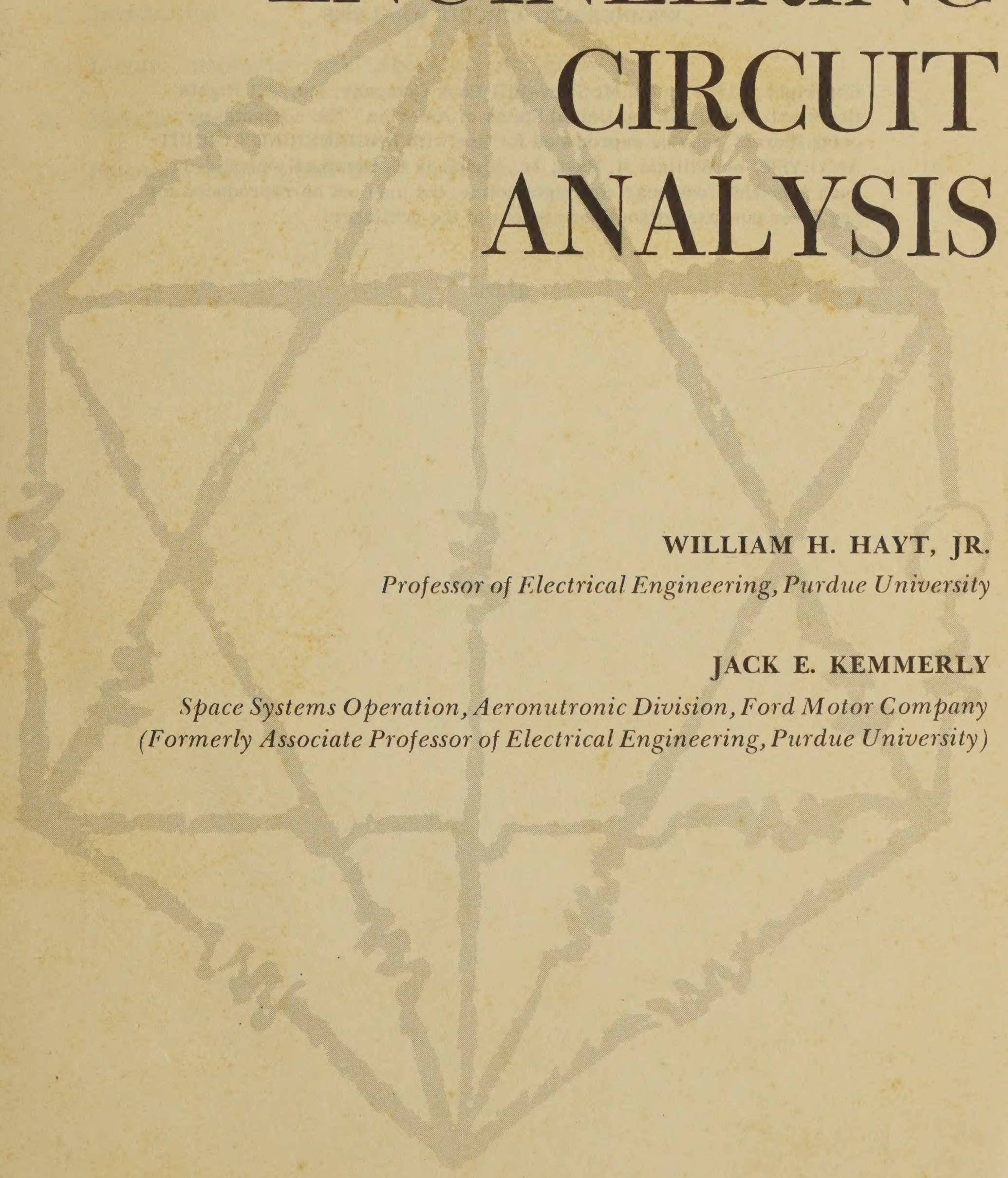
INSTRUCTOR'S MANUAL *to accompany*

ENGINEERING CIRCUIT ANALYSIS



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McGRAW-HILL BOOK COMPANY, INC.
New York San Francisco Toronto London

INSTRUCTOR'S MANUAL TO ACCOMPANY

ENGINEERING CIRCUIT ANALYSIS

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I. Introduction

This book is intended for use with a first course in electrical engineering offered as a two-semester sequence in the sophomore year. A moderate knowledge of integral and differential calculus is presumed, but no prior acquaintance with differential equations is necessary.

The objectives of these two courses, described below as Circuits I and Circuits II, are given to the students on the first day of class:

Circuits I

1. The ability to analyze resistive circuits of reasonable complexity through the application of Kirchhoff's laws, mesh and nodal analysis, superposition, source transformations, and Thévenin's and Norton's theorems, where "analyze" implies the determination of the voltage, current, or power for any circuit element
2. The ability to determine the complete response of any single energy storage circuit excited by constant sources switched into or out of the circuit
3. The ability to determine the complete response of certain second-order systems (parallel and series *RLC*) excited by constant sources switched into or out of the circuit
4. The ability to determine the sinusoidal forced response, including average-power calculations, of any circuit of reasonable complexity

Circuits II

1. Primary objectives:
    a. The ability to characterize impedance and admittance functions and to interpret the natural and forced responses of simple *RLCM* networks through a knowledge of the locations of the poles and zeros of the function or response in the complex-frequency plane
    b. A proficiency in the use of steady-state analytical methods for *RLCM* networks excited by forcing functions of the form $\mathbf{K}_m \epsilon^{\mathbf{s}t}$
2. Secondary objectives:
    a. An understanding of resonant phenomena and the ability to use engineering approximations in determining the response at or near resonance
    b. The ability to determine **z**, **y**, or **h** parameters for an active resistive two port, and to use these parameters to determine input and output impedance and voltage, current, and power gain
    c. An elementary understanding of the applications of topology to network analysis
    d. An elementary understanding of the simpler methods of analysis of balanced polyphase systems
    e. An elementary understanding of the methods of Fourier analysis

The specific courses offered at Purdue University contain two lectures, two recitations, and one 3-hour laboratory period each week for 16 weeks. Each lecture or recitation period is 50 minutes long. The lectures have been given to large sections in the past, but at the present time they are offered to small sections of 25 students by closed-circuit television through the use of video tape. This method permits showing and describing devices, performing experiments and demonstrations, exhibiting printed data or graphs, demonstrating mechanical analogies, maintaining identical progress in many sections, and providing similar courses simultaneously to off-campus centers.

Each lecture is associated with a recitation period for which a special set of problems is assigned. Although the text suggests that all the drill problems be worked, only the most industrious student will find sufficient time. About one-half are normally assigned, three or four per recitation period, as well as three or four problems selected from the group at the end of the chapter.

Given below is a possible schedule for lecture subjects, assigned reading material, typical problem assignments, and brief descriptions of some possible laboratory experiments. Four sample tests are shown for each course. The problem answers not given at the end of the text are also included.

II. Lecture, Recitation, and Laboratory Assignments

Circuits I

WEEK 1

Lecture A: Current, voltage, power, and the circuit element: Chap. 1.
Recitation A: Probs. D1-2, D1-4, D1-5, D1-6, D1-7, P1-9, P1-11.
Lecture B: Ohm's law, Kirchhoff's law, and the single-loop circuit: Secs. 2-1 to 2-4.
Recitation B: Probs. D2-1, D2-5, D2-6, P2-3, P2-15, P2-16.
Laboratory: Introduction to electrical engineering laboratories: the laboratory bench, switches, circuit breakers, fuses, ammeter and voltmeter use, resistance measurement.

WEEK 2

LA: Single node pair circuit, resistance and source combination: Secs. 2-5 and 2-6.
RA: D2-9, D2-10, D2-13, P2-20, P2-26, P2-27.
LB: Voltage and current division, determinants; Secs. 2-7 and 3-3 (in part).
RB: D2-14, D3-3, P2-32, P2-38, P3-6.
Laboratory preparation (discussion of next experiment and assignment of reading, calculation, and curve preparation; about 1.5 hours in class and 1.5 hours homework): galvanometer experiment.

WEEK 3

LA: Mesh analysis: Secs. 3-1 and 3-2.
RA: D3-1, D3-2, P3-1, P3-2, P3-3, P3-5.
LB: Mesh analysis: Sec. 3-3.
RB: D3-4, P3-4, P3-7, P3-11, P3-14.
Lab: Performance of galvanometer experiment: winding, suspending, and calibrating a 50-ma movement; use of shunts and multipliers to construct various ammeters and voltmeters from the basic movement.

WEEK 4

LA: Nodal analysis: Sec. 3-4.
RA: D3-5, P3-17, P3-18, P3-19.
LB: Test 1.
RB: Discussion of test.
Lab prep: D-c measurements.

WEEK 5

LA: Source transformations: Sec. 3-5.
RA: D3-7, D3-9, P3-21, P3-23, P3-29.
LB: Linearity and superposition: Sec. 3-6.
RB: D3-10, D3-11, P3-31, P3-33.
Lab: D-c measurements: measurement of internal resistance of ammeter and voltmeter, measurement of resistance using nonideal instruments, determination and application of Thévenin equivalent circuit.

WEEK 6

LA: Thévenin's and Norton's theorems: Sec. 3-7.
RA: D3-12, D3-14, P3-40, P3-43, P3-45.
LB: The inductor and capacitor: Sec. 4-1 to 4-4.
RB: D4-1, D4-2, D4-3, D4-4, D4-6, D4-10, P4-5, P4-11.
Lab prep: Comparison and null-detection measurements.

WEEK 7

LA: *RLC* circuit fundamentals, duality: Secs. 4-5 to 4-8.
RA: D4-11, D4-12, D4-13, D4-14, P4-26, P4-33.
LB: The simple *RL* circuit and the exponential response: Secs. 5-1 to 5-3.
RB: D5-1, D5-2, D5-4, P5-3, P5-12.
Lab: Comparison and null-detection measurements: use of potentiometer and standard cell to measure unknown voltages, and use of Wheatstone bridge; sensitivity and accuracy.

WEEK 8

LA: More general *RL* circuits: Sec. 5-4.
RA: D5-5, D5-6, D5-7, P5-11, P5-18.
LB: Test 2.
RB: Discussion of test.
Lab prep: The cathode-ray oscilloscope.

WEEK 9

LA: The *RC* circuit: Secs. 5-5 and 5-6.
RA: D5-8, D5-10, D5-12, P5-27, P5-31, P5-32.

LB: The unit-step function and the complete response of *RL* and *RC* circuits: Chap. 6.
RB: D6-2, D6-3, D6-5*a*, D6-6*a*, D6-7*a*, D6-8*a*, D6-9*a*, D6-10*a*, P6-1*d* and *e*, P6-26.
Lab: The cathode-ray oscilloscope: use of all controls, voltage measurement, exponential waveform, sinusoidal waveform, Lissajous figures.

WEEK 10

LA: The source-free parallel *RLC* circuit: Secs. 8-1 to 8-5.
RA: D8-1, D8-3, D8-5, D8-6, P8-7, P8-10.
LB: The series *RLC* circuit, complete response of *RLC* circuits: Secs. 8-6 and 8-7.
RB: D8-8, D8-9, D8-10, P8-13, P8-14.
Lab prep: *RL*, *RC*, and *RLC* transients.

WEEK 11

LA: The sinusoidal forcing function: Chap. 9.
RA: D9-2, D9-3, D9-4, D9-5*a*, P9-3, P9-6.
LB: Complex numbers: Secs. 10-1 to 10-5.
RB: D10-1, D10-2, D10-3*a*, D10-4*a* and *b*, D10-5*b*, D10-7*a*, D10-9*a*, P10-2, P10-5.
Lab: *RL*, *RC*, and *RLC* transients: experimental determination of time constant for *RL* and *RC* circuits; overdamped, underdamped, and critically damped response.

WEEK 12

LA: Complex powers and roots, the complex forcing function: Secs. 10-6 and 10-7.
RA: D10-11, D10-12, D10-13, P10-20*a*, P10-23.
LB: Test 3.
RB: Discussion of test.
Lab prep: The analog computer.

WEEK 13

LA: The phasor: Sec. 10-8.
RA: D10-14, D10-15, D10-16, D10-17, P10-26.
LB: Impedance and admittance: Secs. 10-9 to 10-11.
RB: D10-18, D10-19, D10-20*a*, D10-21*a*, D10-22, P10-25, P10-37.
Lab: The analog computer: generation of step, ramp, and second-order ramp functions; response of first-order system; generation of sinusoid; underdamped, overdamped, and critically damped responses.

WEEK 14

LA: Sinusoidal steady-state response: Secs. 11-1 to 11-5.
RA: D11-1*a*, D11-3*a*, D11-5, D11-7, P11-10, P11-15.
LB: Phasor diagram: Sec. 11-6.
RB: D11-8, D11-9, P11-21, P11-24.
Lab prep: The digital computer.

WEEK 15

LA: Frequency response: no reading assignment.
RA: P11-22, P11-23, P13-22.
LB: Average power and the wattmeter: Secs. 12-1 to 12-4.
RB: D12-1, D12-3, D12-5, D12-7, D12-8, P12-6.
Lab: The digital computer: basic principles of a digital computer; programming an RPC-4000 computer with PINT; analysis and programming the solution of a nonlinear circuit problem; preparation of tapes; operation of computer and numerical solution. Note: Detailed printed material on programming the RPC-4000 and a 50-minute film are available from the Electrical Engineering School, Purdue University, Lafayette, Indiana, on request.

WEEK 16

LA: Effective value, power factor, and complex power: Secs. 12-5 to 12-7.
RA: D12-9, D12-13, D12-14, P12-9, P12-12.
LB: Test 4.
RB: Discussion of test.
Lab prep: Review and makeup.

Circuits II

WEEK 1

LA: Review of complete response: Sec. 8-7.
RA: D8-11, P8-22, P8-29, P11-24.
LB: Exponential forcing function: Secs. 13-1 and 13-2.
RB: D13-1*c*, D13-2, D13-3, P13-1*a*, P13-9, P13-11.
Lab prep: Use of the wattmeter.

WEEK 2

LA: Frequency response: Secs. 13-3 and 13-4.
RA: D13-6, D13-8, D13-11, P13-26.
LB: Complex frequency: Secs. 14-1 and 14-2.
RB: D14-1, D14-2, D14-4, D14-5, P14-1, P14-3.
Lab: Use of the wattmeter: theory and construction of the wattmeter; ranges, scale factors, polarity, and overloading; measurement of power delivered to resistive and resistive-inductive loads.

WEEK 3

LA: **Z**(**s**), **Y**(**s**), and the complex-frequency plane: Secs. 14-5 and 14-6.
RA: D14-7, D14-10, D14-12, P14-9*d*, P14-11, P14-21.
LB: The complex-frequency plane and natural response: Secs. 14-6 and 14-7.
RB: D14-14, D14-15, D14-16, P14-25, P14-27.
Lab prep: Measurement of impedance and transfer functions.

WEEK 4

LA: Immittance loci: Secs. 15-1 and 15-2.
RA: D15-1, D15-2, D15-3, P15-1, P15-2, P15-3.
LB: Test 1.
RB: Discussion of test.
Lab: Measurement of impedance and transfer functions: measurement of phase angle on CRO; use of magnitude and frequency scaling; determination of magnitude and phase angle of input impedance and voltage-transfer function of simple *RC* low-pass coupling network; asymptotic behavior.

WEEK 5

LA: Immittance loci: Sec. 15-3.
RA: D15-5, D15-7, P15-8, P15-11, P15-13*b*, P15-17.
LB: Parallel resonance: pp. 445-452.
RB: D15-9, D15-10, D15-11, P15-29, P15-31, P15-32.
Lab prep: Nonlinear circuit components.

WEEK 6

LA: Parallel resonance: pp. 452-456.
RA: D15-12, D15-13, D15-14, P15-43, P15-44, P15-45.
LB: Series resonance: Sec. 15-5.
RB: D15-15, D15-16, P15-51, P15-55, P15-56, P15-59.
Lab: Nonlinear circuit components: experimental determination of the volt-ampere characteristics of a semiconductor diode, a thermistor, a light bulb, and a varistor; the volt-ampere characteristic of a two-terminal biased diode network; the transfer characteristics of a thermistor compressor circuit and a varistor clipping circuit.

WEEK 7

LA: Other forms of resonant circuits: Sec. 15-6.
RA: D15-18, D15-19, D15-20, P15-60, P15-62*a* and *b*, P15-66.
LB: Scaling: Sec. 15-7.
RB: D15-21, D15-23, D15-24, P15-71*a*, P15-73.
Lab prep: Parallel resonance.

WEEK 8

LA: Mutual inductance: Secs. 16-1 and 16-2.
RA: D16-1, D16-2, D16-4, P16-1, P16-4, P16-7.
LB: Test 2.
RB: Discussion of test.
Lab: Parallel resonance: determination of effective resistance of inductor; providing a current source; frequency calibration of test oscillators; frequency response of high- and low-Q circuit; discussion of Q-meter in lab prep.

WEEK 9

LA: Energy considerations; the air-core transformer: Secs. 16-3 and 16-4.
RA: D16-5, D16-8, D16-11, D16-12, P16-17, P16-20.
LB: The ideal transformer: Sec. 16-5.
RB: D16-13, D16-14, D16-15, P16-22, P16-26.
Lab prep: Voltmeter types and response to nonsinusoidal waveforms.

WEEK 10

LA: One-port networks: Secs. 17-1 to 17-3.
RA: D17-1, D17-2, D17-3, D17-4, P17-1, P17-2.
LB: Admittance parameters: Sec. 17-4.
RB: D17-5, D17-7, P17-3, P17-4, P17-5.
Lab: Voltmeter types and response to nonsinusoidal waveforms: properties of a vacuum-tube voltmeter, a dynamometer voltmeter, and a d-c voltmeter including rectifier; measurement of three unknown voltage waveforms with each meter (waveforms may be rectangular pulse, sawtooth, half-wave rectifier output, pure sine-wave, etc., delivered via power amplifier or low-impedance source to all benches); determination of waveform by CRO and explanation.

WEEK 11

LA: Some equivalent networks: Sec. 17-5.
RA: D17-8, D17-9, D17-10, P17-9, P17-10, P17-11, P17-12.
LB: Impedance and hybrid parameters: Secs. 17-6 and 17-7.
RB: D17-12, D17-13, D17-15, D17-16, P17-19, P17-21.
Lab prep: Coupled coils.

WEEK 12

LA: Topology, loop equations: Secs. 18-1 to 18-3.
RA: D18-1, D18-2, D18-3, D18-4, D18-5, P18-4.
LB: Test 3.
RB: Discussion of test.
Lab: Coupled coils: the T and π equivalents of a pair of coupled coils are determined by making open- and short-circuit measurements of equivalent induct-

ance; series-aiding and series-opposing, as well as resonance methods, are used to determine mutual inductance and mutual reciprocal inductance (Γ_{12}).

WEEK 13

LA: Nodal equations, and the choice between loop and nodal methods: Secs. 18-4 and 18-5.
RA: D18-6, D18-8, D18-9, P18-10, P18-12, P18-16.
LB: Single-phase and two-phase three-wire systems: Secs. 19-1 to 19-3.
RB: D19-1, D19-2, D19-3, D19-4, P19-3.
Lab prep: Nonlinear active two ports.

WEEK 14

LA: Three-phase Y-Y connection: Sec. 19-4.
RA: D19-5, D19-6, D19-7, D19-8, P19-8.
LB: The delta connection: Sec. 19-5.
RB: D19-9, D19-10, P19-12, P19-13, P19-15.
Lab: Nonlinear active two ports: the linear equivalent of a grounded-grid amplifier; the range of validity; theoretical and experimental gain and input impedance.

WEEK 15

LA: Power measurement in three-phase systems: Sec. 19-6.
RA: D19-11, D19-12, D19-13, P19-20, P19-23.
LB: Fourier series: Secs. 20-1 and 20-2.
RB: D20-1, D20-2, P20-3.
Lab prep: Polyphase circuits.

WEEK 16

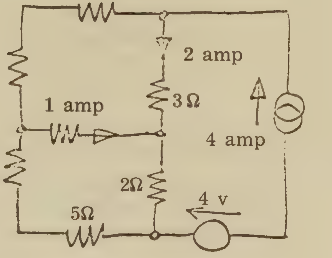
LA: Fourier series: Secs. 20-3 and 20-4.
RA: D20-3, D20-4, D20-5, P20-12, P20-17.
LB: Test 4.
RB: Discussion of test.
Lab: Polyphase circuits: phase-sequence determination; power measurement in a balanced three-phase resistive load, a balanced three-phase *RL* load, and an unbalanced three-phase *RL* load.

III. Sample Tests

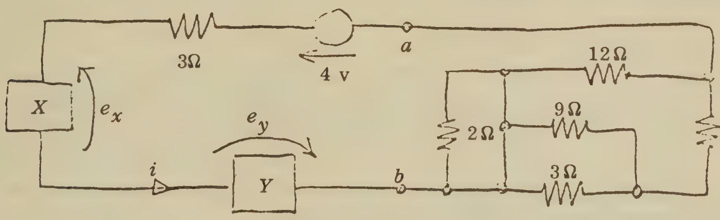
Each of the four sample tests given below for Circuits I and the four for Circuits II is designed to produce a class average of about 70. The test period is 50 minutes long.

Test 1—Circuits I

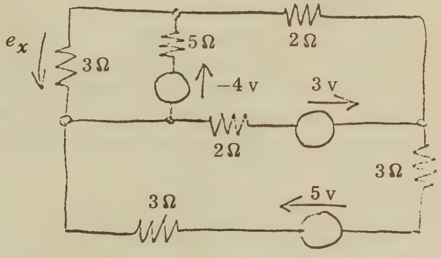
1. (20 points) Find the power absorbed by (a) the current source; (b) the voltage source; (c) the 5-ohm resistor.



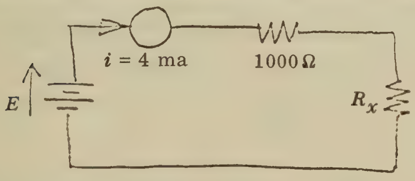
2. (30) If $i = 3$ amp and $e_y = 4$ volts, (a) find e_x; (b) find the power supplied by element X. (Hint: First find the equivalent resistance between terminals a and b.)



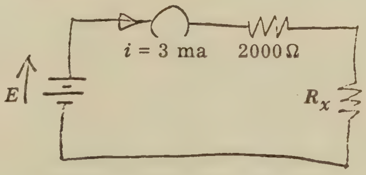
3. (30) (a) Write a set of mesh equations for this circuit. (b) Find e_x.



4. (20) In order to find the value of an unknown resistance R_x, a student uses a battery of unknown voltage, an ammeter, and some known resistors to perform the two experiments shown below. Determine the value of R_x.



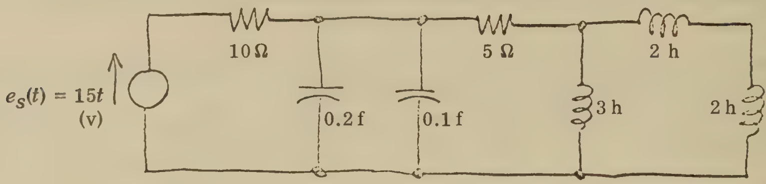
Experiment 1



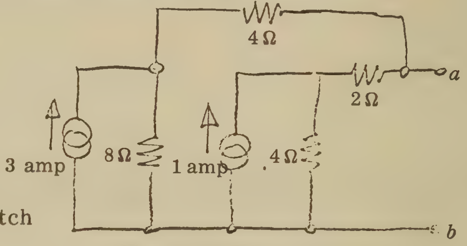
Experiment 2

Test 2 — Circuits I

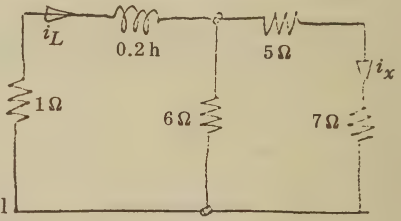
1. (a) (5) Reduce the circuit shown below to a two-mesh circuit. (b) (15) Write the two mesh equations for the circuit.



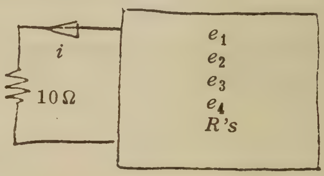
2. (30) Determine the Thévenin and Norton equivalents of this circuit. Sketch your solutions with proper designation of elements.



3. (25) Find $i_x(t)$ if $i_L(0) = 8$ amp. Sketch and dimension your solution.

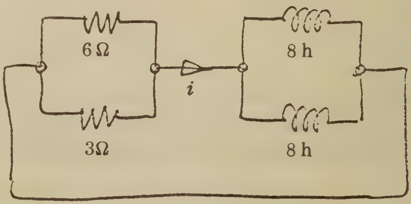


4. A linear resistive network contains four ideal voltage sources, e_1, e_2, e_3, and e_4. With e_1 and e_2 "killed," the current i is 2 amp. With e_1 killed, i is 3 amp. With e_3 and e_4 killed, i is -4 amp. (a) (15) With all four sources operating, what will be the current i? (b) (10) With all four sources operating, e_1 is increased by a factor of k, and $i = 6$ amp. Find k.



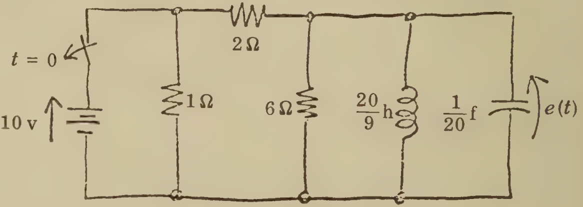
Test 3 — Circuits I

1. (20) If $i(0) = 9$ amp, find $i(t)$ for $t > 0$.

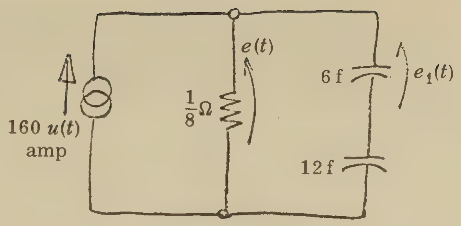


2. (15) (a) Evaluate in polar form: $5 - j3$. (b) Evaluate in rectangular form: $10\underline{/206.5^\circ}$.

3. (30) The switch in the circuit below has been closed for a long time; it is opened at $t = 0$. Find $e(t)$ for $t > 0$.

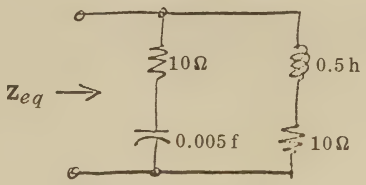


4. Given: $e(0) = 5$ volts and $e_1(0) = 2$ volts, (a) (25) find $e(t)$ for $t > 0$; (b) (10) find $e_1(t)$ for $t > 0$.

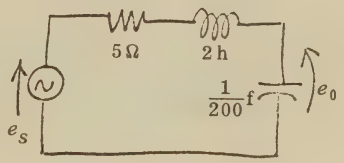


Test 4 — Circuits I

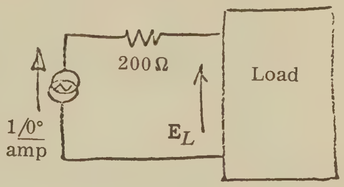
1. (25) Find $\mathbf{Z}_{eq}$ at $\omega = 20$ radians/sec.



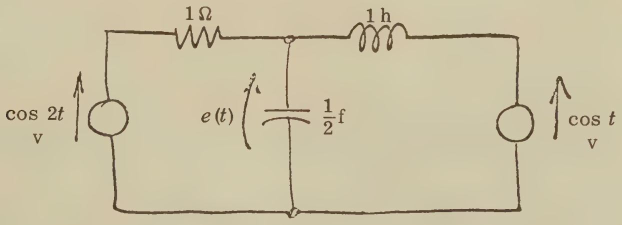
2. (30) The circuit has been operating for a very long time. If $e_s = 60 \cos (10t - 40°)$ volts, find the value of e_0 at $t = \pi/10$ sec.



3. (30) If the average power absorbed by the load is 50 watts at a 0.5 leading power factor, (a) find $\mathbf{E}_L$; (b) find the average power delivered by the current source.

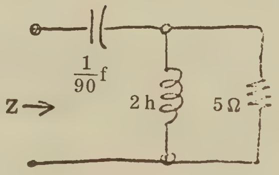


4. (15) For the circuit below, find $e(t)$.

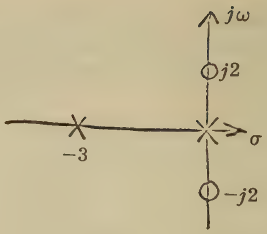


Test 1 — Circuits II

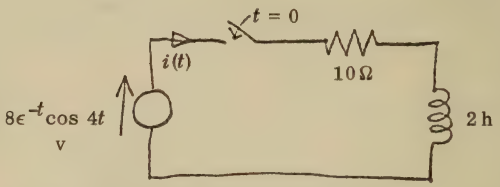
1. (25) For the network shown, write $\mathbf{Z}$ as a function of $\mathbf{s}$. Sketch the pole-zero constellation. Evaluate $\mathbf{Z}$ for $\mathbf{s} = \sigma = -5$ sec^{-1}.



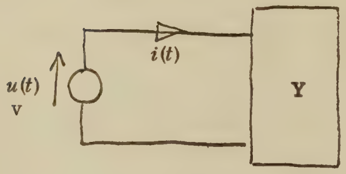
2. (25) The pole-zero plot of $\mathbf{Z}(s)$ is shown. Find the magnitude and phase angle of the impedance at $\omega = 3\sqrt{3}$ radians/sec, if $|\mathbf{Z}(j3)| = 10/\sqrt{2}$ ohms.

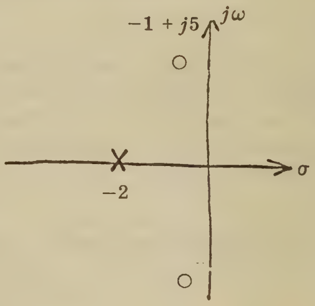


3. (25) Find $i(t)$ for $t > 0$.

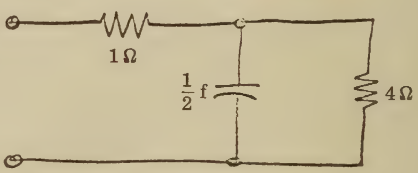


4. (25) The pole-zero configuration shown applies to the input admittance of the accompanying network. The network is excited by a unit step of voltage. Determine the response $i(t)$, evaluating as many constants as possible.



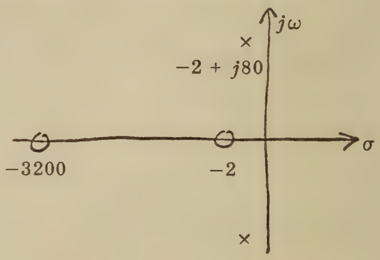


Test 2—Circuits II

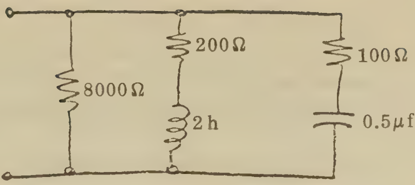


1. (25) (a) Draw the impedance locus of the given network. Label all important points. (b) Draw the new impedance locus if the capacitance is doubled. (c) Draw the new impedance locus if the original network is "scaled in magnitude by a factor of 2" and "scaled in frequency by a factor of 3."

2. (25) The pole-zero constellation shown applies to an input admittance. (a) Find ω_0, Q_0, $\mathcal{B}$, ω_1, and ω_2. (b) If $\mathbf{Z}(j\omega_0) = 5\underline{/0^\circ}$ ohms, find $\mathbf{Z}(j\omega_2)$.



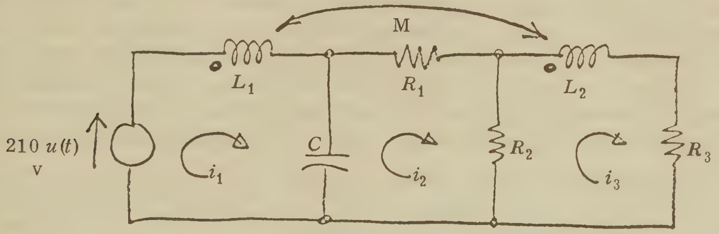
3. (25) **(a)** Convert the given network to a simple parallel *RLC* network which is equivalent near resonance. **(b)** What is the approximate value of Q_0 for the given network?



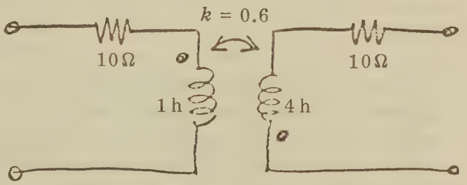
4. (25) A pendulum consists of a weightless arm 2 meters long with a bob on the end having a mass of 540 grams. The pendulum is given a small displacement and released. As the bob passes the lowest point from right to left, its velocity is 30 cm/sec; on the next (right to left) swing, its velocity is 29 cm/sec. Remembering that the kinetic energy of the pendulum as it passes its lowest point is $\frac{1}{2}mv^2$, find Q_0 for this pendulum.

Test 3 — Circuits II

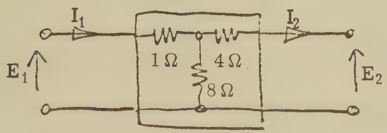
1. (25) For the circuit shown below, write the mesh equations for $t > 0$. No energy storage is present at $t = 0$.



2. (25) Find the **z** parameters if $\omega = 5$ radians/sec.



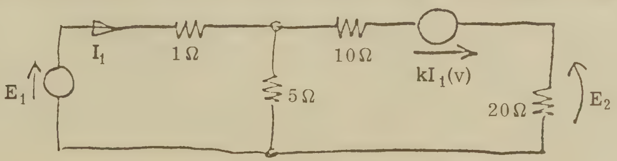
3. (25) The **ABCD** parameters are defined by the two equations below. Note the assumed direction of $\mathbf{I}_2$. **(a)** The admittance parameters are defined by relationships of the form: $\mathbf{y}_{11} = \left.\frac{\mathbf{I}_1}{\mathbf{E}_1}\right|_{\mathbf{E}_2=0}$. Define the parameter **A** by a similar relationship. **(b)** Determine the numerical value of **A** and state its units.



$$\mathbf{E}_1 = \mathbf{A}\mathbf{E}_2 + \mathbf{B}\mathbf{I}_2$$

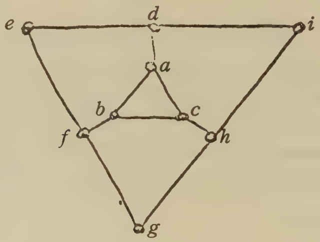
$$\mathbf{I}_1 = \mathbf{C}\mathbf{E}_2 + \mathbf{D}\mathbf{I}_2$$

4. (25) Find the value of **k** which will lead to an infinite output voltage $\mathbf{E}_2$.



Test 4 — Circuits II

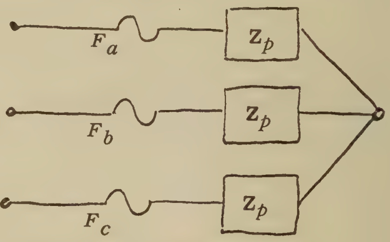
1. (25) For the circuit represented by the linear graph below, **(a)** how many independent loop currents are required? **(b)** Show why or why not the following set of node pair voltages represents an independent set.



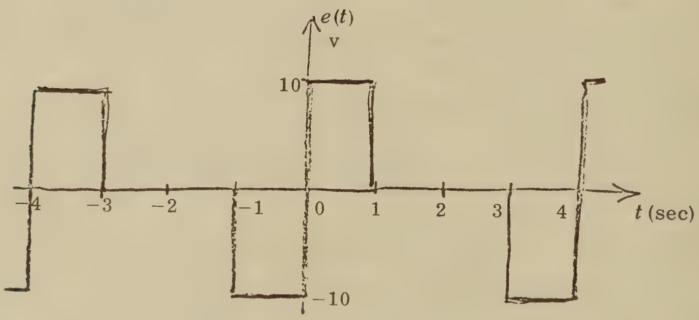
$(e_a - e_b)$
$(e_b - e_f)$
$(e_c - e_a)$
$(e_e - e_d)$
$(e_f - e_g)$
$(e_g - e_h)$
$(e_h - e_c)$
$(e_i - e_d)$

2. (25) A three-phase Δ-connected source supplies a digital computer through conductors each having a resistance of 0.15 ohms. The line voltage at the source is 440 volts rms. The computer load is Y-connected. When the computer is on stand-by, the load is $30.3\underline{/36.8^\circ}$ ohms per phase; when operating fully, the load is $2.40\underline{/30^\circ}$ ohms per phase. The engineer who designed the system guarantees that, under full load, the voltage at the computer will not drop below 240 volts rms line-to-neutral. Show whether or not he is correct.

3. (25) The balanced three-phase load shown is operated with a phase voltage of 120 volts rms. Three 10-amp (rms) fuses are used. $Z_p = 5 + j12$ ohms. **(a)** For some unknown reason fuse F_c blows. Show whether or not fuses F_a and F_b blow by finding the steady-state current in each. **(b)** Suggest a wiring change which will make the power supplied to each load fairly independent in the event a fuse blows in one phase. Fuse protection should be provided in each phase.



4. (25) For the waveform shown, find the amplitude of **(a)** the fundamental; **(b)** the seventh harmonic.



IV. Problem Answers (Not Given in Text)

Chapter 1

(2) (a) 5.3 coulombs. (b) $i = -3t^2 + 14t - 11$. (4) (a) 0.250 amp. (b) 0.162 amp. (c) 1.62 coulombs. (7) (a) 24 volts. (b) 1/6 amp. (8) (a) 16.02×10^{-6} amp. (b) 6.24×10^{6} volts. (10) See Fig. 1. (11) (a) −6 watts. (b) 10/3 volts. (c) 4 amp.

Chapter 2

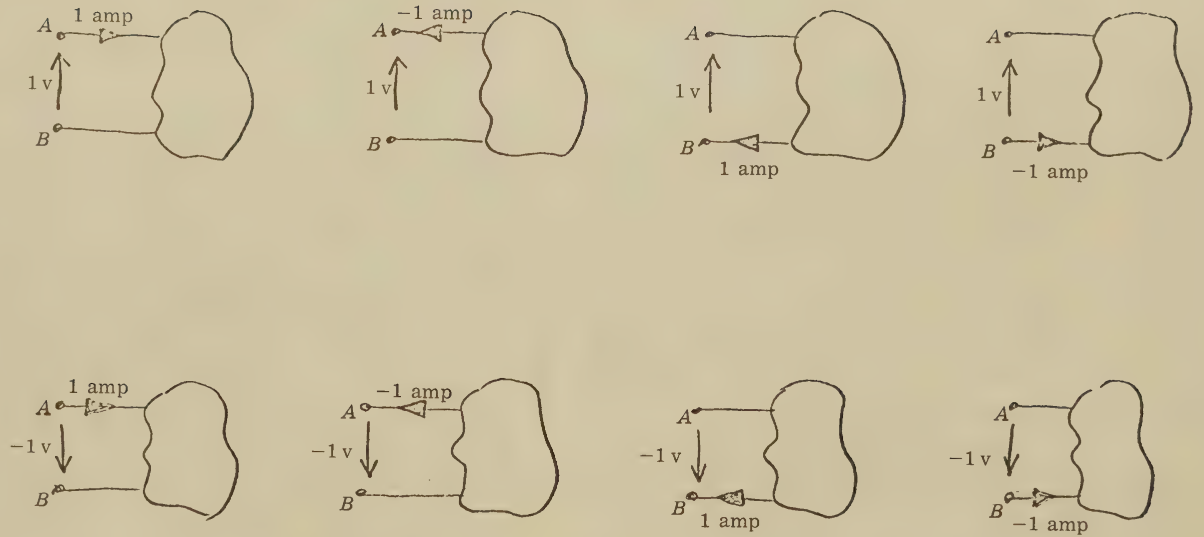
(2) Proof. (4) (a) 0.01085 volt. (b) 0.552 amp. (c) 5.61 in. (5) (a) 1.05, 1.15, 1.25, and 1.35 amp. (b) 1.0, 1.1, 1.2, 1.3, and 1.4 amp. (c) 12.1, 14.4, 16.9, and 19.6 watts. (d) 58.1 joules. (7) (a) 47 watts. (b), (c), and (d) See Fig. 2. (9) −1.77 amp, 0.156 volt. (11) (a) 0.00125 ohm/ft. (b) No. 10 wire. (13) Clockwise from the 10-volt source, powers are: −2 watts, 0.08 watt, 0.12 watt, 1.6 watts, 0.2 watt. (15) (a) 6 amp. (b) −2 amp. (c), (d), and (e) 4 amp. (18) From left to right, powers are: 3.6 watts, −7.2 watts, 0.576 watt, 1.152 watts, 1.872 watts. (20) (a) From left to right, powers are: 8 watts, 16 watts, −56 watts, 32 watts. (b) Absorbing; $R = 8$ ohms, $e_s = 8$ volts, $i_s = 1$ amp. (c) From left to right, powers are: −104 watts, 16 watts, 56 watts, 32 watts. Delivering; $e_s = 8$ volts, $i_s = 13$ amp. (21) (a) 120 volts, 12 amp. (b) 240 watts. (c) 1200 watts. (d) 40 watts, 1000 watts. (23) 3 amp. (25) (a) 6 ohms. (b) 6 ohms. (c) 4 ohms. (27) 5.5 volts, 3.975 amp. (29) −10 watts, 0 watt, 8 watts, 2 watts, −1 watt, 1 watt. (31) From left to right, powers are: 25/18 watts, 2/9 watt, 2 watts. (33) (a) 12 watts. (b) 0 watt. (34) (a) 187.5 watts. (b) One solution is a 115-volt source in series with eight 41.3-ohm bulbs. (36) (a) $R_{\text{error}} = R_a$, $R_{\text{error}} = -R^2/(R + R_v)$. (b) $R = \frac{1}{2}(R_a + \sqrt{R_a^2 + 4R_aR_v})$. (c) Circuit of Fig. 2-44*b*. (38) (a) 0.89 amp, −7.1 watts, 0.8 watts, 6.3 watts. (b) 2.0 amp, −24 watts, 8 watts, 16 watts.

Chapter 3

(2) Proof. (4) (a) See Fig. 3. (b) See Fig. 4. (7) (a) 1.2 amp. (b) No. (c) 1.523. (9) 1.97 watts, −0.447 watt, 0.331 watt. (10) See Fig. 5. (12) 5 amp. (14) From left to right, powers are: 152 watts, 403 watts, 51 watts, 13 watts, 102 watts, 61 watts. $P_{int\ batt} = 4.8$ watts, $P_{int\ gen} = 19.2$ watts. (16) R_BR_C/R_A. (18) 0 volt. (20) $G = 1/R = R_A/R_BR_C$. (22) 3 amp. (24) Same as Prob. 23. (25) Proof; yes; no; $R_{int} = R_L$. (26) (a) Proof. (b) Proof. (28) 200 volts in series with 40 ohms, and 5 amp in parallel with 40 ohms. (30) −8.33 volts. (32) (a) 10 volts. (b) 10 volts. (c) Proof. (34) 1.414 amp. (36) (a) $de/di = -R_s$; straight-line, e-intercept is e_s, i-intercept is e_s/R_s. (b) 283 volts in series with 70.7 ohms. (38) See Fig. 6. (40) 24 volts in series with 45.5 ohms. (42) 30 volts in series with 2 ohms. (43) (a) $R_{th} = R/(1 - gR)$. (b) i_s in parallel with $R_1(1 + K)$ ohms, and $i_sR_1(1 + K)$ volts in series with $R_1(1 + K)$ ohms. (45) R_2e_{s1}/R_1 volts in series with R_2 ohms. (46) (a) 0.6 amp. (b) 0.6 amp. (c) Current in 150-ohm load should be 0.5 amp. (47) −1/3 volt. (49) (a) 7.5 ohms. (b) 18 ohms. (c) 10.5 volts.

Chapter 4

(1) (a) 500 volts, $0 \le t < 0.01$ sec; −1000 volts, $0.01 < t < 0.015$ sec. (b) $i = 5000t$ amp, $0 \le t \le 500$ μsec; 2.5 amp, $t \ge 500$ μsec. (3) See Fig. 7. (6) (a) 0, 0, and 1.25 amp. (b) 12, 12, and 12 amp. (7) (a) 50 ma, $0 < t < 1$ msec; 0 ma, 1 msec $< t <$ 3 msec; −100 ma, 3 msec $< t <$ 3.5 msec. (b) $e = 5 \times 10^6 t$, $0 \le t \le 1$ msec; $e = 5000$ volts, $t \ge 1$ msec. (9) (a) 5 amp, $0 < t < 1$ sec; 0 amp, $1 < t < 2$ sec; 5 amp, $2 < t < 3$ sec; −10 amp, $3 < t < 4$ sec; 0 amp thereafter. (b) 3 sec. (c) 10 joules. (12) (a) 0, 0, and


A
1 amp
1 v
B
A
−1 amp
1 v
B
A
1 v
B
1 amp
A
1 v
B
−1 amp
A
1 amp
−1 v
B
A
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B
A
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B
1 amp
A
−1 v
B
−1 amp

Fig. 1

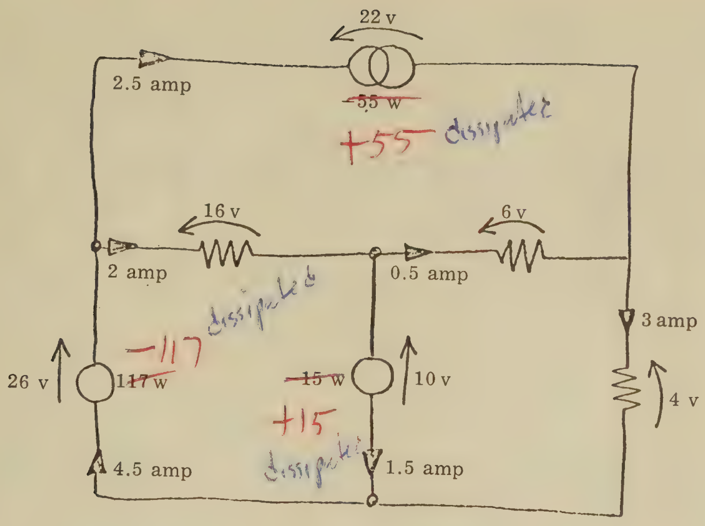


Fig. 2

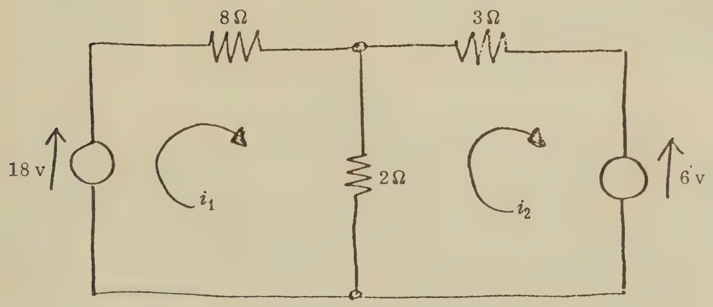


Fig. 3

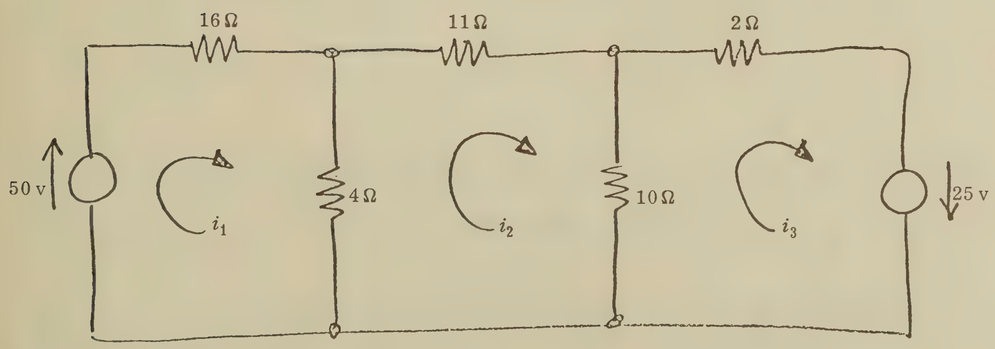


Fig. 4

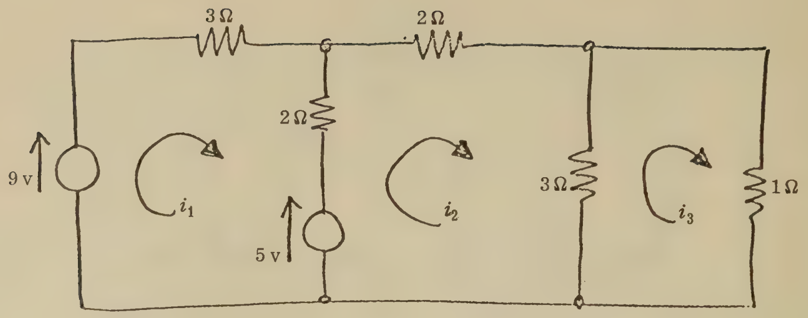


Fig. 5

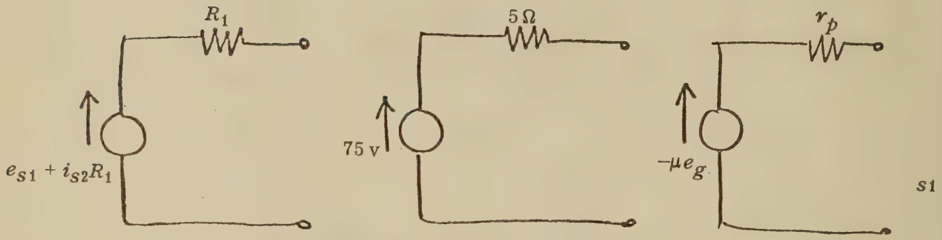


Fig. 6

30 volts. (b) 120, 120, and 120 volts. (13) For $t < 0$, $e_L = e_C = e_s = 0$; for $0 < t < 1$ sec, $e_L = 15$ volts, $e_C = 12.5t^2$ volts, $e_s = 15 + 12.5t^2$; for $1 < t < 2$ sec, $e_L = -15$ volts, $e_C = 25 - 12.5(2 - t)^2$ volts, $e_s = 10 - 12.5(2 - t)^2$ volts; for $t > 2$ sec, $e_L = 0$, $e_C = 25$ volts, $e_s = 25$ volts. (15) (a) 60.2 μhenrys. (b) 0.362 ohm. (16) (a) 0.01796 μf. (b) 49.2 megohms. (c) Proof. (18) (a) Proof. (b) $w_C = q^2/2C$, $w_C = qe/2$. (19) $e_R(0) = 50$ volts, $e_L(0) = 0$, $e_C(0)$ is a function of $e_C(t_0)$. (22) $e_s = iR_{eq} + L_{eq}\frac{di}{dt} + \frac{1}{C_{eq}}\int_{t_0}^{t} i\,dt + e_C(t_0)$, where $R_{eq} = R_1(R_2+R_3)/(R_1+R_2+R_3)$, $L_{eq} = L_1 + (L_2L_3)/(L_2+L_3)$, $C_{eq} = C_3 + (C_1C_2)/(C_1+C_2)$. (23) (a) $i_R = -0.02\epsilon^{-t/5}$. (b) $i_L = 2.5(1 - \cos 200t)$. (25) (a) 1/3 henry, 1/12 farad. (b) $e_R = 10 \cos 6t$. (c) $e_s = 10 \cos 6t$. (26) $L_{eq} = \frac{di_1}{dt} + \frac{1}{C_1}\int_{t_0}^{t} i_1 dt + e_{C1}(t_0) + i_1R_1 - i_2R_1 = e_{s1}$, $-i_1R_1 + i_2R_1 + i_2R_2 + C_{eq}\int_{t_0}^{t} i_2 dt + e_{C_{eq}}(t_0) = -e_{s2}$, where $L_{eq} = L_1L_2/(L_1 + L_2)$, and $C_{eq} = (C_2 + C_3 + C_4)/C_4(C_2 + C_3)$. (28) $\frac{e_A}{R_1} + C_1\frac{d(e_A - e_B)}{dt} + \frac{1}{L_1}\int_{t_0}^{t}(e_A - e_C)dt + i_{L1}(t_0) = \frac{e_1}{R_1}$; $C_1\frac{d(e_B - e_A)}{dt} + C_2\frac{d(e_B - e_C)}{dt} + \frac{1}{L_2}\int_{t_0}^{t} e_B dt + i_{L2}(t_0) = 0$; $\frac{e_C}{R_2} + C_2\frac{d(e_C - e_B)}{dt} + \frac{1}{L_1}\int_{t_0}^{t}(e_C - e_A)dt + i_{L1}(t_0) = \frac{e_2}{R_2}$. (32) See Fig. 8. (33) See Fig. 9. (34) (a) 1 volt in series with 1 ohm. (b) 1-amp source, 1 ohm, and $\frac{1}{3}$ ohm in parallel. (c) The parallel combination of 3-amp source, 0.5 ohm, and 1 ohm in series

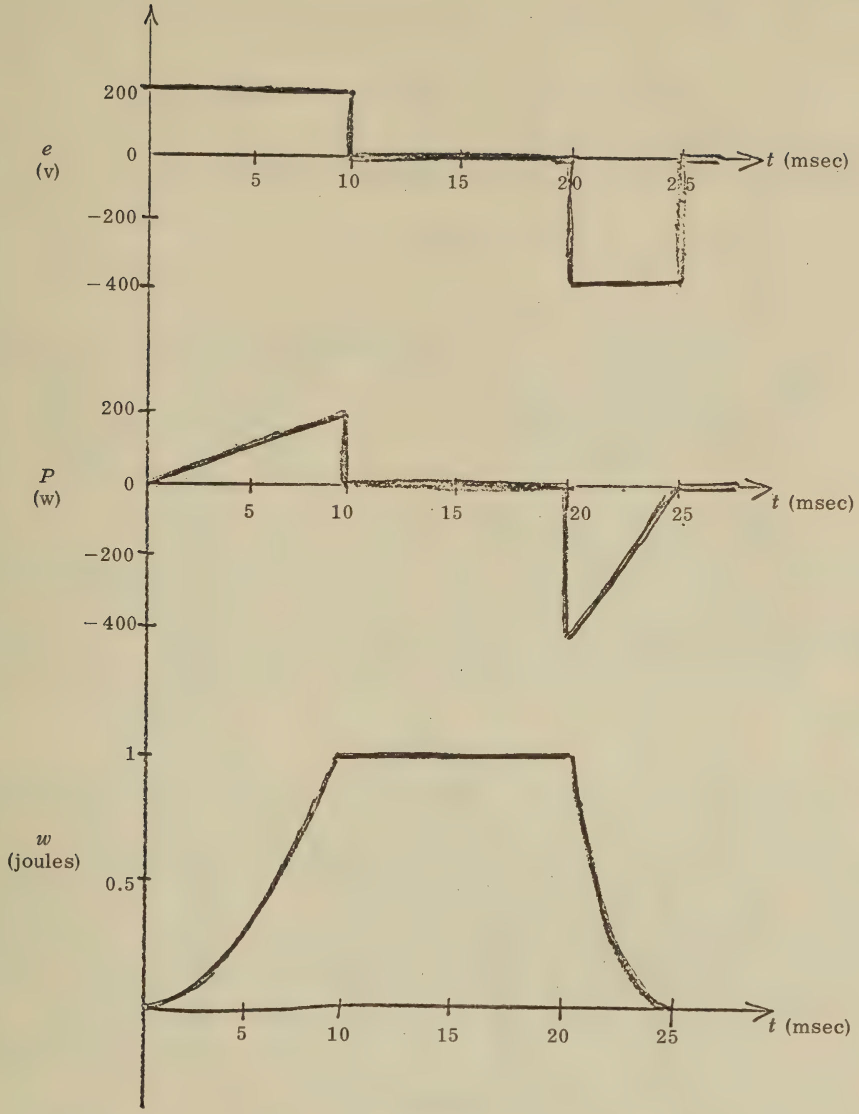
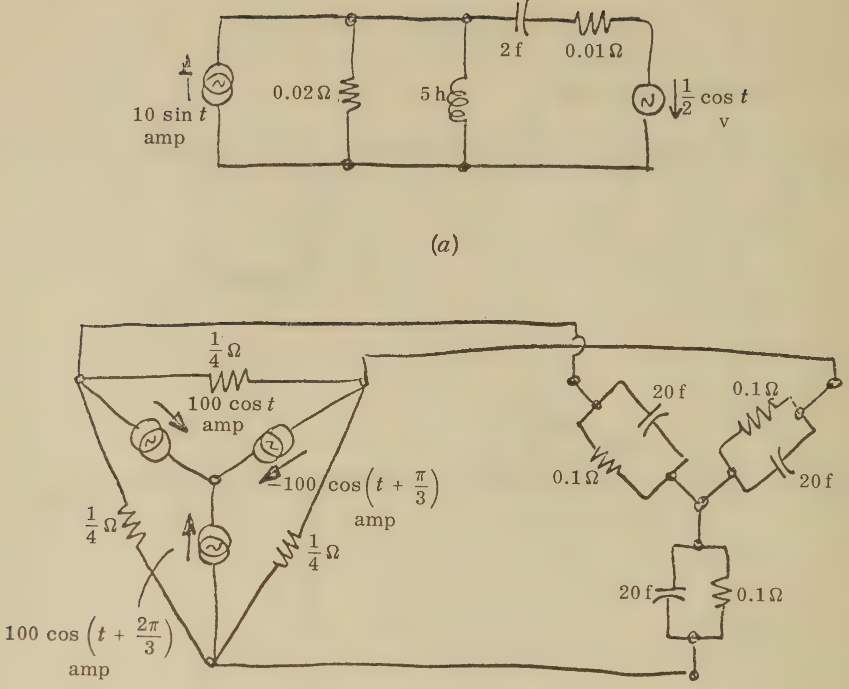


Fig. 7

with the parallel combination of 3 ohms and 1/3 ohm. **(d)** 1-amp source, 1 ohm, and 1/3 ohm in parallel. **(36)** Proof. **(38)** $i_1 = \epsilon^{-t}$, $i_2 = 0.5\,\epsilon^{t} + 0.5\epsilon^{-t}$, $i_3 = -0.5\epsilon^{t} + 0.5\epsilon^{-t}$. **(40)** $e_1 = \cos 3t$, $e_2 = -2.5 \cos 3t$, $e_3 = 3.5 \cos 3t$.

Chapter 5

(2) 17.45 amp, 182.7 joules. **(4)** $12.5\epsilon^{-5t}$ amp. **(6)** **(a)** $20\epsilon^{-100t}$ amp. **(b)** 0.01 sec. **(c)** 100 joules. **(d)** 3.47 msec. **(e)** $-1000\epsilon^{-100t}$ volts. **(f)** $-1000\epsilon^{-100t}$ volts. **(g)** -2000 amp/sec. **(h)** 4.46 amp. **(7)** **(a)** $m\,dv/dt + dv = 0$. **(b)** 5.73 m/sec. **(c)** 80 m. **(9)** Energy is dissipated in an arc across switch; it ionizes air mole-



(*a*)

(*b*)

Fig. 8

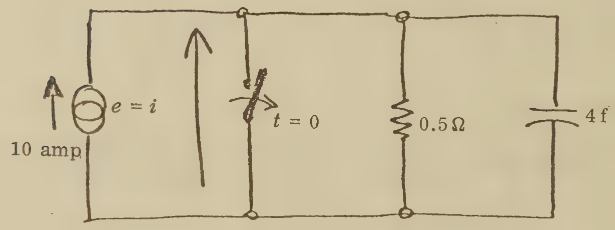


Fig. 9

cules. An arc may be avoided by using a "switch" that gradually changes resistance from zero to infinity; sometimes a specific size capacitor may be installed in parallel with the switch. (11) $e = -100{,}000\epsilon^{-2000t}$. (13) For $t < 0$, $i_1 = 2$ amp, $i_2 = 8$ amp; for $t > 0$, $i_1 = -8\epsilon^{-2.5t}$ amp, $i_2 = 8\epsilon^{-2.5t}$ amp. (14) $i_L = 1$ amp for $t < 0$, and $i_L = \epsilon^{-2t}$ amp for $t > 0$. (17) (a) $-2.67\,\epsilon^{-2220t}$ amp. (b) $2.67\epsilon^{-25t}$ amp. (c) $2.67\epsilon^{-100{,}000t}$ amp. (18) (a) 0 volt. (b) 120 volts. (c) 60 volts. (d) 0.0299 sec. (20) $w_1(0) = 384$ joules, $w_1(\infty) = 96$ joules; $w_2(0) = 48$ joules, $w_2(\infty) = 48$ joules; $w_3(0) = 144$ joules, $w_3(\infty) = 0$. (22) Proof. (24) 59.2 volts, 175 joules. (25) (a) $i_R = 0.01\epsilon^{-10{,}000t}$ for $t > 0$. (b) 12.5 μjoules. (27) (a) $100\epsilon^{-t/14}$ volts. (b) $10{,}000\epsilon^{-t/7}$ joules. (c) 14 sec. (d) 22.3 volts. (e) 0 volt. (29) (a) $84\epsilon^{-t/10.5}$ volts.

(b) $7056\epsilon^{-t/5.25}$ joules. (c) 10.5 sec. (d) 11.37 volts. (e) 0 volt. (31) $e_1 = 80\epsilon^{-t/10} - 60$, $e_2 = 40\epsilon^{-t/10} + 60$, for $t \geq 0$. (33) 10 ohms, 1 millihenry. (35) $i_1 = \frac{10}{3}\epsilon^{-t} + \frac{5}{3}\epsilon^{-0.4t}$, $i_2 = -\frac{10}{3}\epsilon^{-t} + \frac{25}{3}\epsilon^{-0.4t}$, both for $t > 0$.

Chapter 6

(1) See Fig. 10. (3) (a) $12u(t - 0.01)$ volts. (b) $Eu(\mathrm{t} - t_0)$ volts. (c) $20 - 15u(t)$ volts. (d) $3 - 6u(t)$ amp. (e) $u(t)$ volts. (f) $u(t) + 2u(t-1) + 3u(t-2)$ volts. (5) $\frac{e}{R} + C\frac{de}{dt} = I$; $e(t) = IR(1 - \epsilon^{-t/RC})$; $e = 20(1 - \epsilon^{-10^7 t})$ volts; all for $t > 0$. (7) $e = \sqrt{\frac{I_0}{k}} \tanh \frac{\sqrt{kI_0}}{C} t$. (9) $e = \sqrt{\frac{I_0}{k} - \frac{t}{2kL}}$. (12) (a) $i = -4 + 8\epsilon^{-20t}$. (b) $i = 0.1$ amp. (c) $i = \frac{1}{30} + \frac{1}{150}\epsilon^{-150{,}000t}$. (13) See Fig. 11. (15) (a) $i_L = 0.5$ for $t < 0$, $i_L = 0.4 + 0.1\epsilon^{-t/0.64}$ for $t > 0$; (b) $i_x = 1.00$ for $t < 0$, i_x is indeterminate at $t = 0$, $i_x = 1.2 + 0.05\epsilon^{-t/0.64}$ for $t > 0$.
(17) $53.3(1 - \epsilon^{-6t})$ amp, 1422 joules. (19) (a) $i = 1 + 2\epsilon^{-t/2}$. (b) 13.35 joules.
(20) $L_2R_1 = 4L_1R_2$, and $E_1R_2 = E_2R_1$; if $E_1 = E_2$, then $R_1 = R_2$, and $L_2 = 4L_1$.
(22) Replace battery and switch by $30u(t)$ volts; $e_C = 20(1 - \epsilon^{-t/0.7})u(t)$.
(24) (a) $\frac{1}{C_1}\int_0^t i_1 dt + i_1R_1 - i_2R_1 = E \cos \omega t$, $-i_1R_1 + i_2(R_1 + R_2) + \frac{1}{C_2}\int_0^t i_2 dt = 0$. (b) $i_1(0^+) = E/R_1 + E/R_2$, $i_2(0^+) = E/R_2$. (25) (a) $e_C(0)$ is incorrect. (b) The series combination of a 12-volt battery and a switch which opens at $t = 0$ is placed in parallel with the capacitor; $e_C(0) = 12$ volts. (c) $e_C(0)$, e_f, and τ are the same. (27) $e_0 = 60(1 - \epsilon^{-10{,}000t})u(t)$, $i = (5 + 3\epsilon^{-10\,000t})u(t)$ ma. (29) (a) $-0.4\epsilon^{-2t}$ amp. (b) 0.05 joule. (31) (a) $e_1 = E - (E - e_0)\epsilon^{-T/2RC}$. (b) $e_2 = [E - (E - e_0)\epsilon^{-T/2RC}]\epsilon^{-T/2RC}$. (c) $e_2 = E\epsilon^{-T/2RC}/(1 + \epsilon^{-T/2RC})$. (d) $e_1 = E - e_0$. (e) See Fig. 12. (32) (a) and (b) $(12 + 8\epsilon^{-t/6})u(t)$ amp.

Chapter 7

(1) (a) 10^{-4} volt-sec. (b) 0.09 μcoulomb. (c) −0.5 mcoulomb. (d) 0.955 mvolt-sec. (e) 1 coulomb. (f) 2 mvolts-sec. (g) 50 μvolts-sec. (approx.). (3) L volt-sec, L volts. (5) (a) $2.5\ u(t)$ volts. (b) $3.5\ u(t)$ volts-sec. (6) Proof. (7) See Fig. 13. (9) (a) $4\ u(t)$ amp. (b) $6\ u(t)$ amp. (11) See Fig. 14. (12) $e_{s2} = -1.264\,\delta(t-1) - 2\epsilon^{-t}u(t-1)$ volts. (16) (a) $L = 5$ henrys, $R = 10$ ohms, resistor voltage and current unchanged. (b) $L = 5$ henrys, $R = 10$ ohms, resistor voltage and current, and inductor current unchanged. (17) See Fig. 15. (18) See Fig. 16. (20) (a) $20\delta(t)$ amp (b) $20\delta(t) - 0.4\epsilon^{-t/50}u(t)$ amp. (c) $20\delta(t) - 0.4\epsilon^{-t/50}u(t)$ amp. (d) $\frac{40}{3}\delta(t) - \frac{8}{45}\epsilon^{-t/75}u(t)$ amp. (e) $\frac{40}{3}\delta(t) + \frac{292}{45}\epsilon^{-t/75}u(t)$ amp. (21) (a) $\frac{60}{R}\epsilon^{-t/3R}u(t)$ amp. (b) $180\delta(t)$ amp. (c) $120\delta(t)$ amp.

Chapter 8

(1) See Fig. 17. (3) $t_m = 1/(s_1 - s_2) \ln(-s_2A_2/s_1A_1)$. (6) $t_m = 0.582$ sec, $e_m = 44.1$ volts, $t_s = 4.46$ sec. (8) (a) $(19\epsilon^{-t} - 9\epsilon^{-3t})u(t)$ volts. (b) $\epsilon^{-0.02t}(10 \cos 1.73t - 27.4 \sin 1.73t)u(t)$ volts. (10) $\epsilon^{-0.1t}(-5 \cos 0.3t + \sin 0.3t)u(t)$ volts, $i = \epsilon^{-0.1t}(\cos 0.3t - 8 \sin 0.3t)u(t)$ amp. (12) (a) 4 volts, 1 amp. (b) $1.370\epsilon^{-t/8} \cos(1.996t - 43.2°)u(t)$ amp. (c) 1.166 sec. (d) $e_L = -4.72$ volts, $e_R = 0$. (e) −4.72 volts. (f) 0.61 joule.
(14) 2000 ohms, 0.1 henry, 0.02 μf. (16) 4 ohms, 45°. (18) (a) 10 henrys.
(b) 1 sec^{-1}, 20 ohms, 0.1 farad. (20) See Fig. 18. (22) $i = [5.11\epsilon^{-0.1t} \cos(0.3t + 11.3°)]u(t)$. (24) $e = [(160\epsilon^{-2t} - 40\epsilon^{-8t})/3 + 80]u(t)$. (26) Proof. (27) $e(t) = 0$.
(28) Proof. (30) $e = (100 + 2\epsilon^{-t} - \epsilon^{-2t} + 4\epsilon^{-3t})u(t)$. (31) $i = (-0.618\epsilon^{-0.382t} + 1.618\epsilon^{-2.618t})u(t)$. (33) $e = \epsilon^{-5t}(100 - 400t)u(t)$. (35) Let $\alpha = 10^5$; $i = \epsilon^{-5000t}(0.03 \times \cos 10^5 t - 0.0015 \sin 10^5 t)u(t)$. (36) (a) $m(d^2v/dt^2) + Kv = 0$; $\omega_0 = \sqrt{K/m}$.

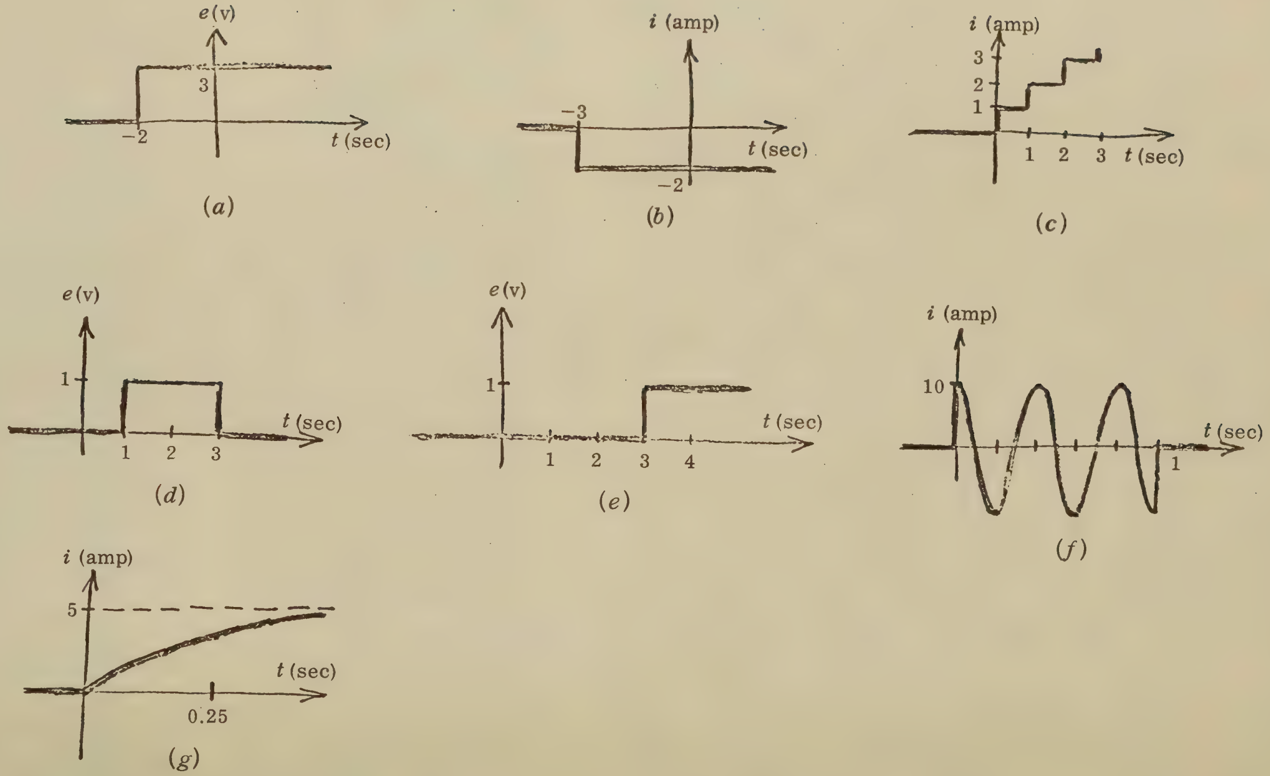

e(v)
3
−2
t (sec)
(a)
i (amp)
−3
t (sec)
−2
(b)
i (amp)
3
2
1
1
2
3
t (sec)
(c)
e(v)
1
1
2
3
t (sec)
(d)
e(v)
1
1
2
3
4
t (sec)
(e)
i (amp)
10
t (sec)
1
(f)
i (amp)
5
t (sec)
0.25
(g)

Fig. 10

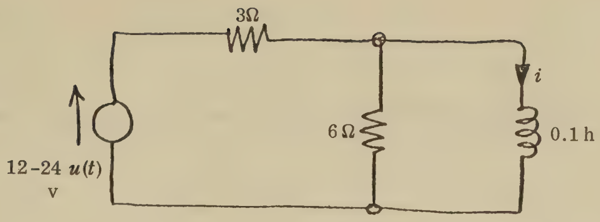
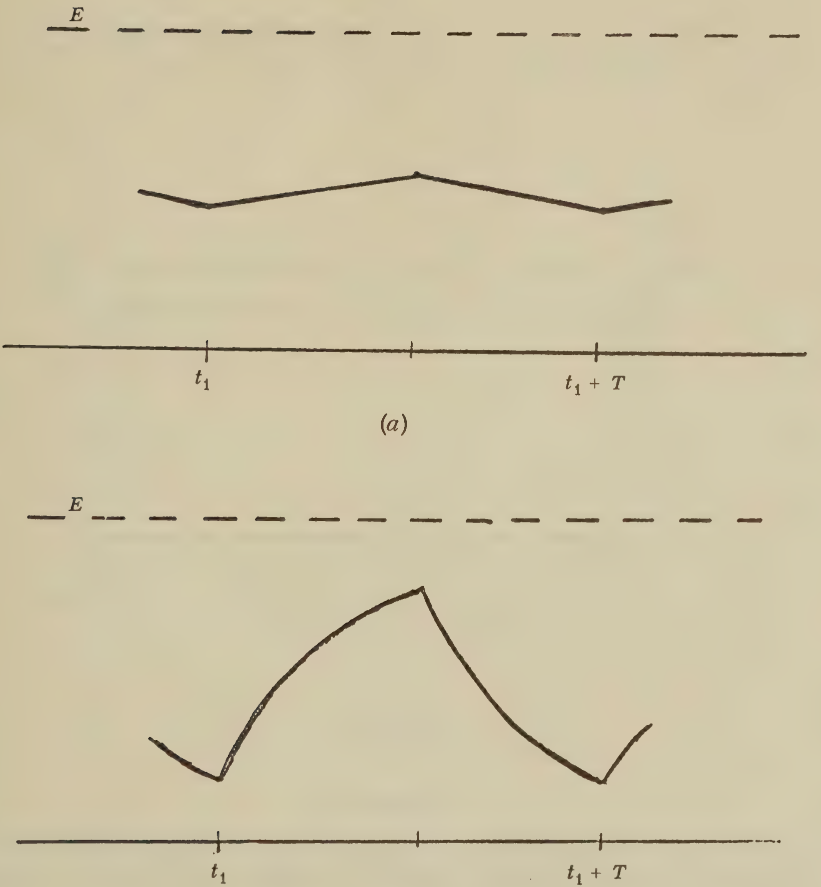


Fig. 11



(a)

(b)

Fig. 12

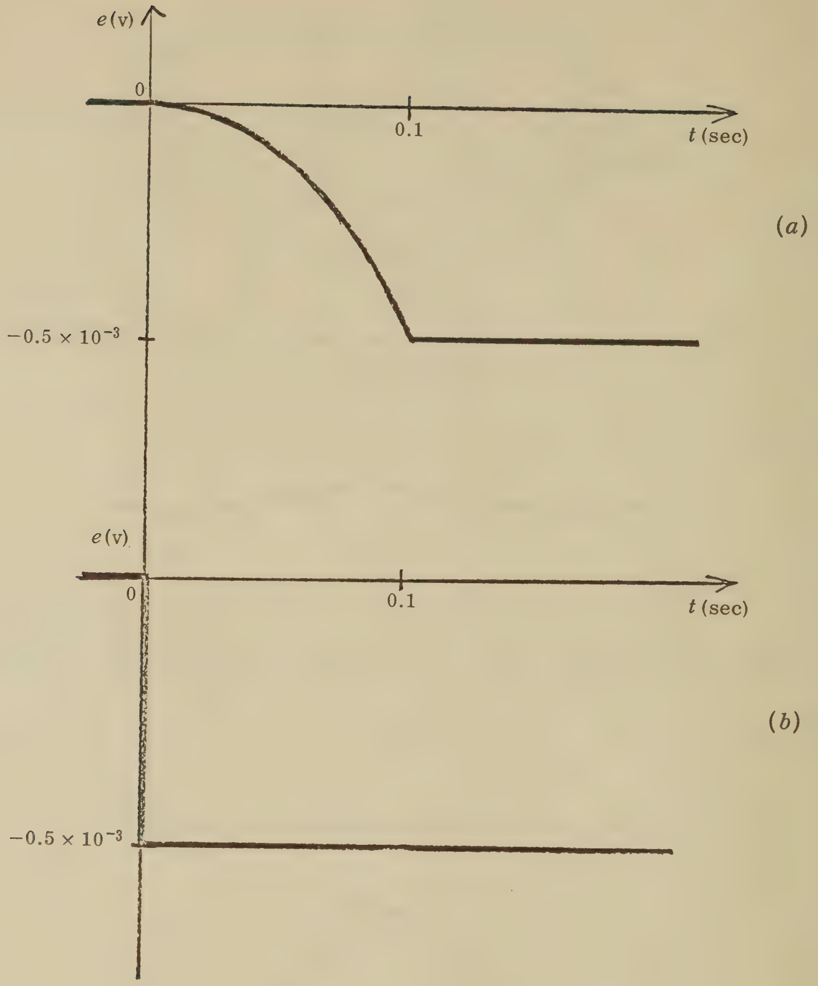


Fig. 13

Chapter 9

(2) Proof. (5) (a) $i = 0.393 \cos 200t - 0.920 \sin 200t$. (b) $i = \cos(200t + 66.9^\circ)$. (c) $i = \sin(200t + 156.9^\circ)$. (6) (a) Proof. (b) $i \cos(200t + 53.1^\circ)$. (c) $e_R = 18 \cos 200t - 24 \sin 200t$; $e_C = 24 \sin 200t + 32 \cos 200t$. (8) $i = 0.6 \cos 200t + 0.8 \sin 200t - 0.6\epsilon^{-150t}$. (10) $E_m \cos \omega t = L\dfrac{di}{dt} + \dfrac{1}{C}\displaystyle\int_{t_0}^{t} i\,dt + e_C(t_0)$; $i_f = [\omega C E_m/(\omega^2 LC - 1)] \sin \omega t$. (11) Given: $i = \dfrac{E_m}{\sqrt{R^2 + \omega^2 L^2}} \cos\left(\omega t - \tan^{-1} \dfrac{\omega L}{R}\right)$; then: $e = \dfrac{I_m}{\sqrt{(1/R_1^2) + \omega^2 C^2}}$ $\times \cos(\omega t - \tan^{-1} \omega C R_1)$; $i = \dfrac{E_{m1}}{\sqrt{(1/\omega^2 C^2) + R_1^2}} \cos\left(\omega t + \tan^{-1} \dfrac{1}{\omega C R_1}\right)$.

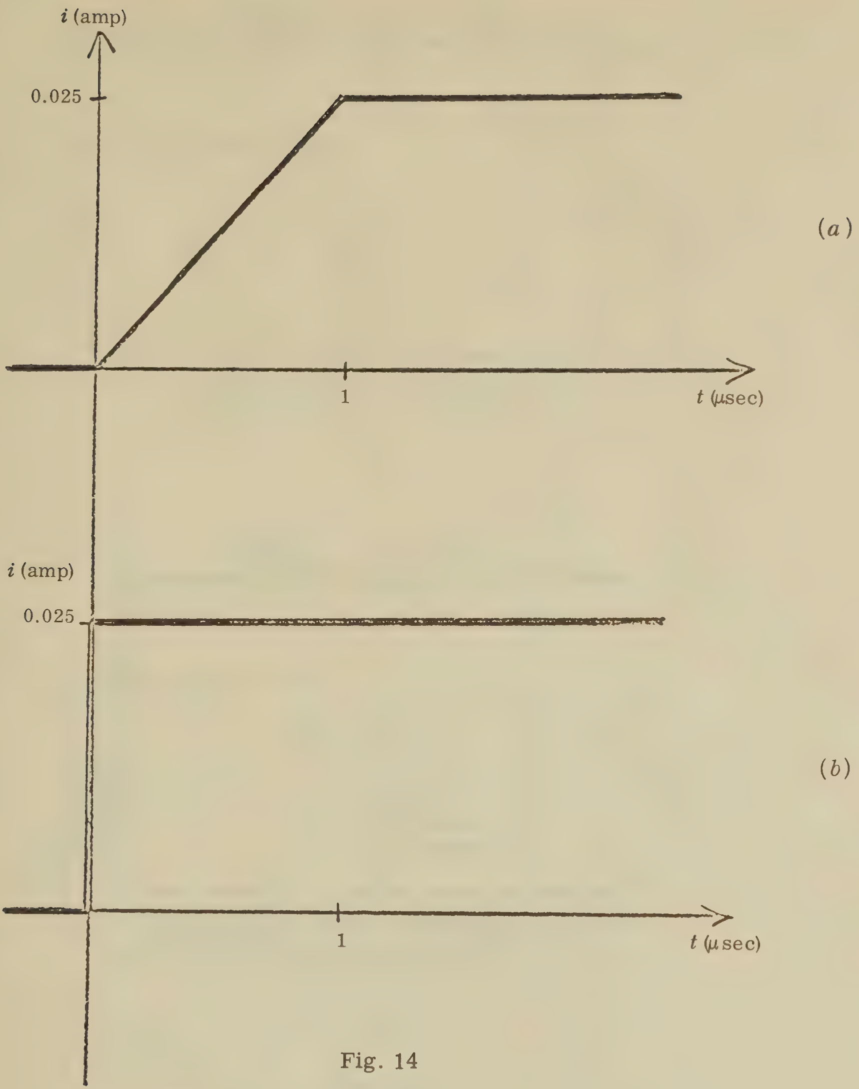
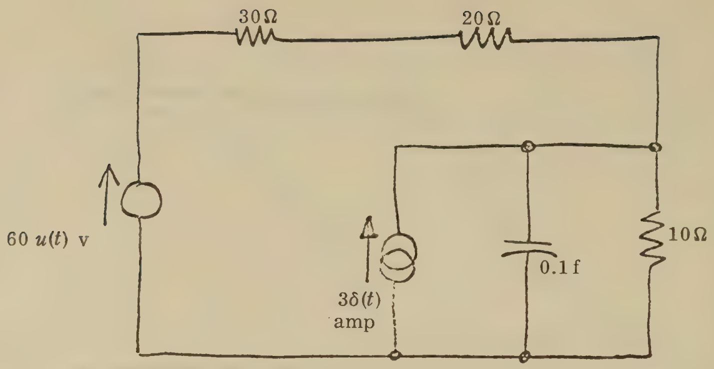


Fig. 14

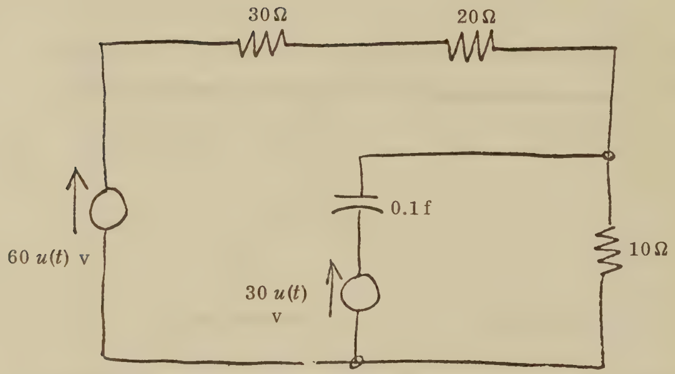
Chapter 10

(3) $2 + j5$.. (4) See Fig. 19. (5) (a) Let $\mathbf{A} = a + jb$; therefore, $\mathbf{A}^* = a - jb$; therefore, $\mathbf{A} + \mathbf{A}^* = 2a$. (b) $\mathbf{A} - \mathbf{A}^* = j2b$. (c) $\mathbf{AA}^* = a^2 + b^2$. (d) Let $\mathbf{A} = a + jb$, and $\mathbf{B} = c + jd$. $\mathbf{AB}^* = ac + bd + j(bc - ad)$. $(\mathbf{A}^*\mathbf{B})^* = [(a - jb)(c + jd)]^* = (ac + bd - jbc + jad)^* = \mathbf{AB}^*$. (7) (a) $-1 \pm j3$. (b) $6 \pm j8$. (c) $1 + j0$, $0 + j1$, $0 - j1$. (9) Proof. (10) (b) $0.995 - j0.0998$. (c) $1.198 - j0.242$. (d) $0.865 - j0.268$. (11) (b) $1.296 - j0.635$. (c) $0.272 + j1.085$. (12) (a) $2.718\epsilon^{j114.6^\circ}$. (c) $8.25\epsilon^{-j14.0^\circ}$. (d) $10.2\epsilon^{j101.3^\circ}$. (e) $5\epsilon^{-j126.9^\circ}$. (13) (b) $-6.00 + j10.4$. (c) $-3.83 - j3.21$. (d) $4.96 - j0.521$. (e) $4.50 + j7.80$. (f) $-0.832 + j1.818$. (15) (a) $j20$. (b) $-3.94 + j9.20$. (c) -4. (16) (a) $-j5$. (b) $0.985 - j2.30$. (c) 1. (17) Proof. (20) (b) $j1.57$. (c) $1.61 + j3.14$. (d) $1.61 + j0.930$. (e) $-1.498 + j2.04$. (21) (a) $1\underline{/39.7^\circ}$. (b) 0.208. (c) $1 + j0.403$. (22) Proof. (23) (a) $2 \sin (10^6 t - 130^\circ)$ amp. (b) $0.4 \sin (10^6 t - 70^\circ)$ amp. (c) $0.8 \sin (10^6 t - 40^\circ) +$



All voltages and currents same for $t > 0^+$.

(a)

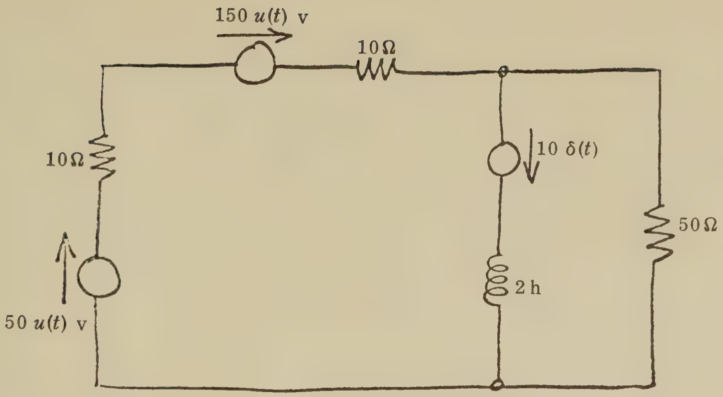


All voltages and currents, except capacitor voltage, same for $t > 0$.

(b)

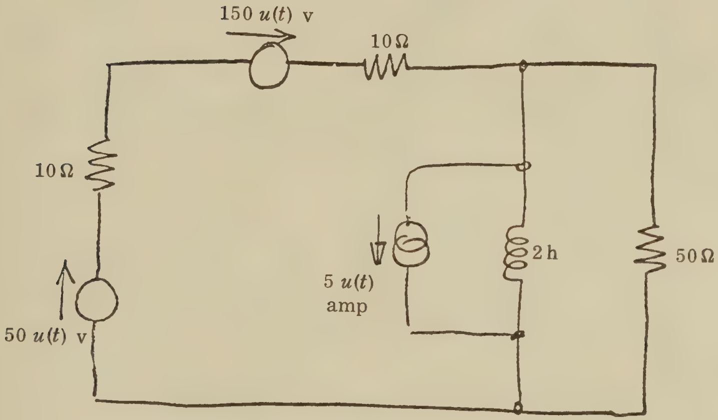
Fig. 15

$j0.8 \sin(10^6 t - 130^\circ)$ amp. (e) Impossible. (24) (a) R. (b) σL. (c) $1/\sigma C$. (25) (a) 150 watts. (b) 0. (c) 0. (26) (a) $130\underline{/0^\circ}$ volts. (b) $\mathbf{E}_S = \mathbf{I}R + j\omega L\mathbf{I}$. (c) $\mathbf{I} = \mathbf{E}_S/(R + j\omega L)$. (d) $i = 10 \cos(10{,}000t - 67.4^\circ)$ amp. (27) (a) $15\underline{/120^\circ}$ volts. (b) $\mathbf{E}_S = 60\mathbf{I} + j80\mathbf{I}$. (c) $\mathbf{I} = 0.15\underline{/66.9^\circ}$ amp. (d) $i = 0.15 \cos(400t + 66.9^\circ)$ amp. (29) (b) (a) $-j6$, 0, -6 ohms; (b) $1.6 - j0.2$, 1.6, -0.2 ohms; (c) $58 + j0$, 58, 0 ohms; (d) $8.92 + j\,0.81$, 8.92, 0.81 ohms. (30) $-j20$, $20 \cos(1000t - 90^\circ)$ amp. (31) $0.1414\underline{/45^\circ}$, $0.1414 \cos(2 \times 10^6 t + 45^\circ)$ volts. (32) (a) $j0.0062$, 0, 0.0062 mho. (b) $-j0.09$, 0, 0.09 mho. (c) $0.0005 - j0.0005$, 0.0005, -0.0005 mho; 1000, 1000 ohms. (d) $10^{-3} - j10^{-3}$, 10^{-3}, -10^{-3} mho; 500, 500 ohms. (f) $10^{-4} + j0$, 10^{-4}, 0 mho; 10,001, 0 ohms. (33) $0.650 - j0.05$ mho. (35) $3.5 - j0.5$ ohms. (36) A 5-ohm resistor.



All currents and voltages same for $t > 0^+$.

(*a*)



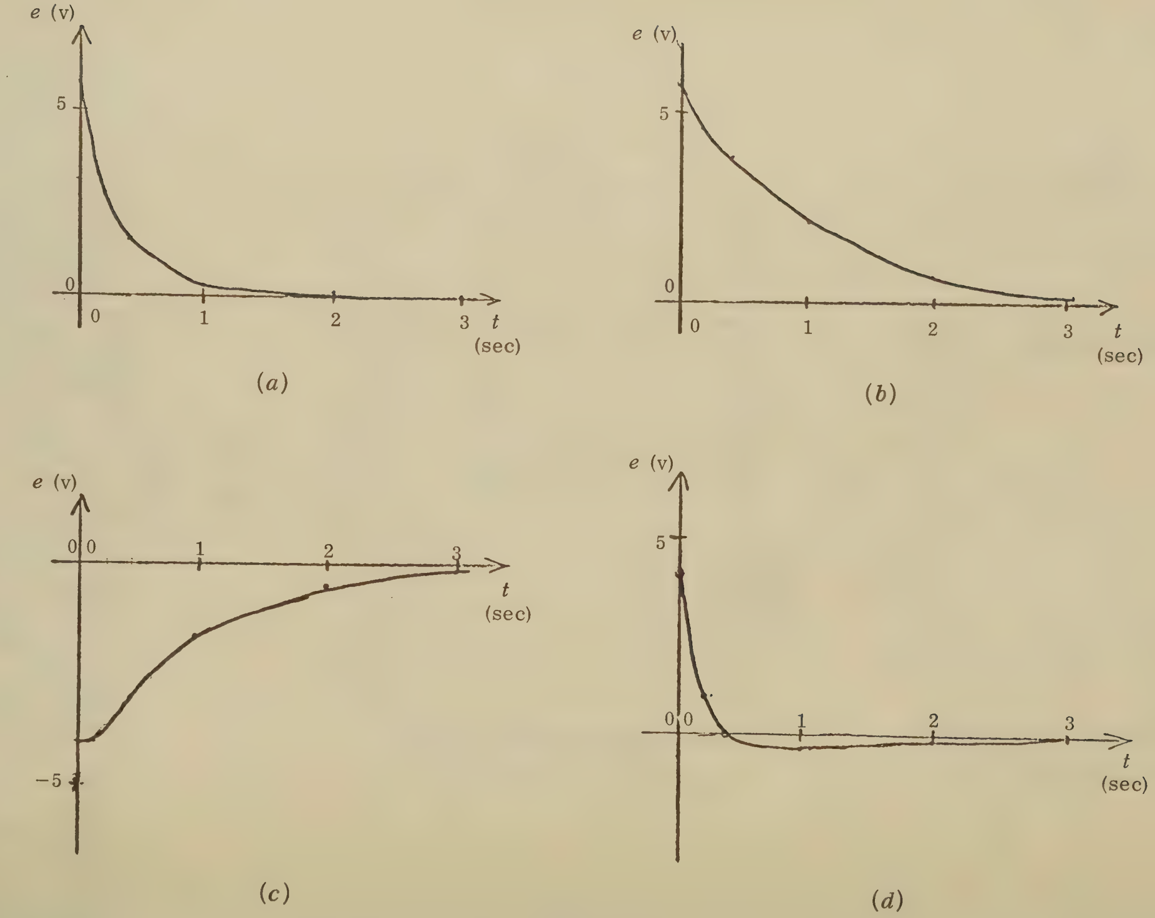
All currents and voltages, except inductor current, same for $t > 0$.

(*b*)

Fig. 16

Chapter 11

(2) $10\underline{/0^\circ}$, $10 \cos \omega t$ volts. (3) $0.4\underline{/180^\circ}$, $0.4 \cos (1000t + 180^\circ)$ amp. (5) $0.447\underline{/63.4^\circ}$, $0.447 \cos (10^7 t + 63.4^\circ)$ volt. (6) $(5 + j3)\mathbf{I}_1 - j3\mathbf{I}_3 = -10 - j10$; $4\mathbf{I}_2 + j4\mathbf{I}_3 = 10 + j10$; $-j3\mathbf{I}_1 + j4\mathbf{I}_2 + (2 + j11)\mathbf{I}_3 = 10 + j5$. (7) Proof; all voltages must have same ω; differs from Kirchhoff's voltage law because voltages need not be around any closed path. (8) $0.4\underline{/180^\circ}$, $0.4 \cos (1000t + 180^\circ)$ volt. (10) Bridge is balanced; $i_L = 0$. (12) $1.2 \sin 5t$ amp in parallel with 10 henrys. (13) $36 - j48$ volts in series with $2.88 - j3.84$ ohms, $12.5\underline{/0^\circ}$ amp in parallel with $2.88 - j3.84$ ohms. (14) $100\underline{/0^\circ}$ volts in series with 0.8 henry, $-j125/\omega$ amp in parallel with 0.8 henry. (16) (a) $5 - j5$ volts in series with $0.5 + j0.5$ ohm. (b) $-j10$ amp in parallel

e (v)
5
0
0
1
2
3
t
(sec)
(a)
e (v)
5
0
0
1
2
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t
(sec)
(b)
e (v)
0
0
1
2
3
t
(sec)
−5
(c)
e (v)
5
0
0
1
2
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t
(sec)
(d)

Fig. 17

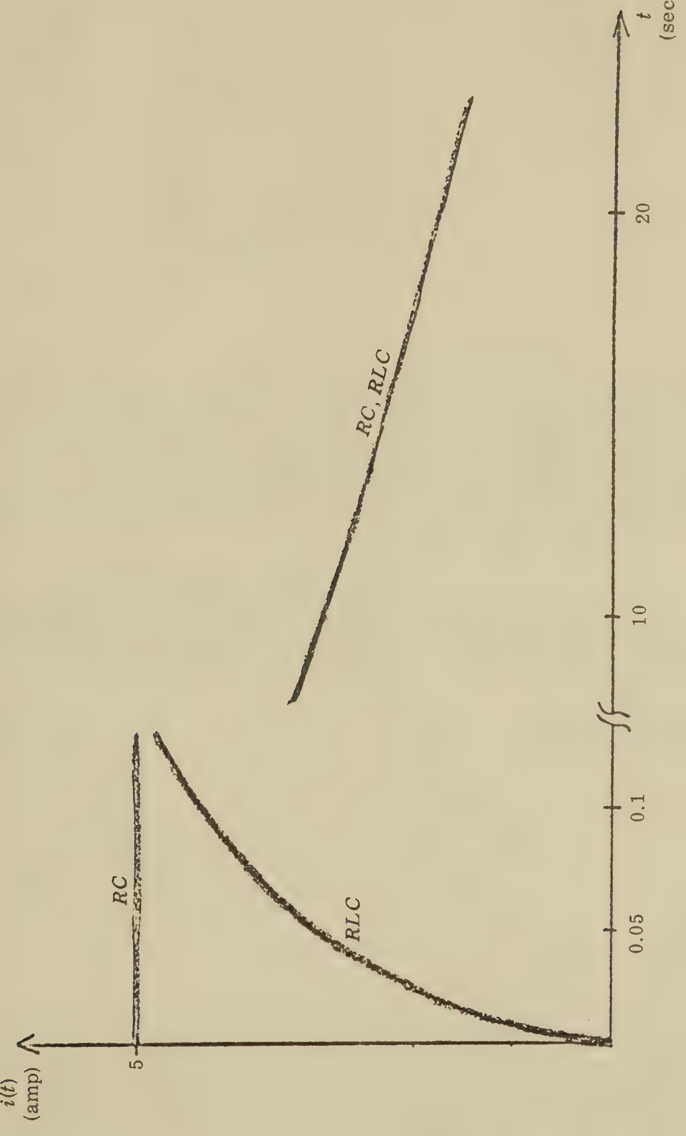


Fig. 18

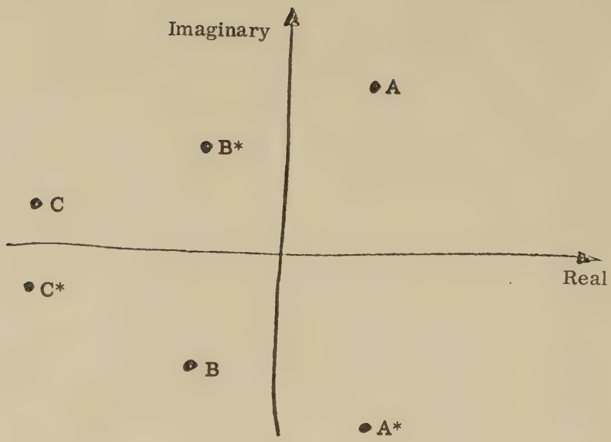
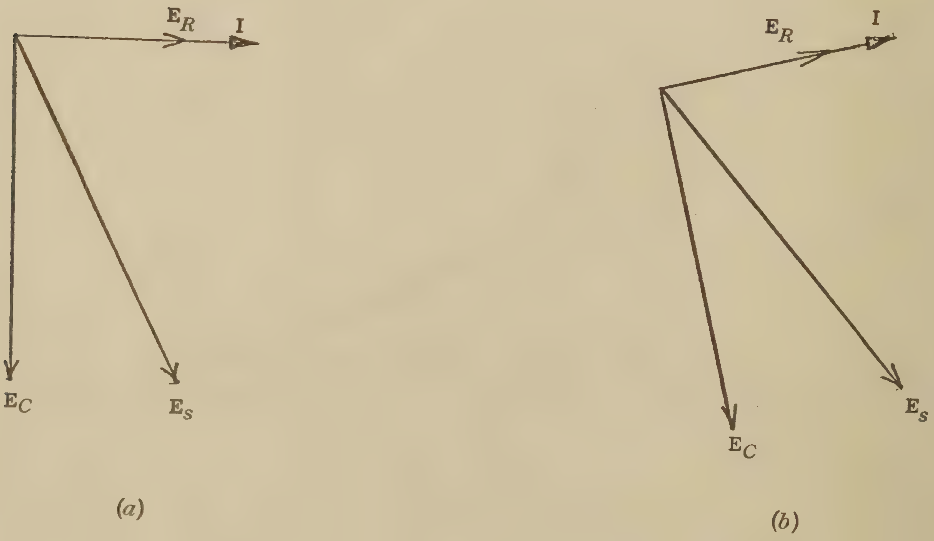


Fig. 19

with 0.5 + j0.5 ohm. (c) Same as (b). (17) j6 volts, 1 + j1 amp, 3 + j3 ohms. (19) See Fig. 20*a*. I leads E_s; 63.4°; ratio is 0.894. (20) See Fig. 20*b*. I leads E_s; 63.4°; ratio is 0.894. (22) (a) See Fig. 21. (b) I lags E_s. (c) and (d) See Fig. 21. (23) (a) $E_A = 50\underline{/\pm 54.9^\circ}$, $E_B = 100\underline{/\pm 24.3^\circ}$. (24) See Fig. 22. (25) (a) $4.71\underline{/0^\circ}$. (b) $4.11\underline{/0^\circ}$. (c) $6.04\underline{/50^\circ}$. (d) $4.71\underline{/0^\circ}$. (26) Relabel Fig. 11-16*b*: E_L, $E_R + E_L$, E_R, E_s, I, E_C, $E_R + E_C$ become I_C, $I_R + I_C$, I_R, I_s, E, I_L, $I_R + I_L$, respectively.

Chapter 12

(1) (a) $p = 250\,(1 - \epsilon^{-t/50})u(t)$. (b) $p = 177 \cos 0.02t \cos (0.02t - 45^\circ)$. (3) (a) P = 250 watts, P_R = 250 watts, P_C = 0. (b) P = 10.5 watts, P_1 = 9 watts, P_3 = 1.5 watts,



(*a*) (*b*)

Fig. 20

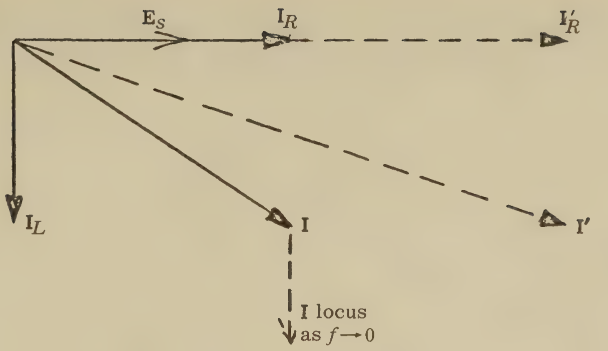


Fig. 21

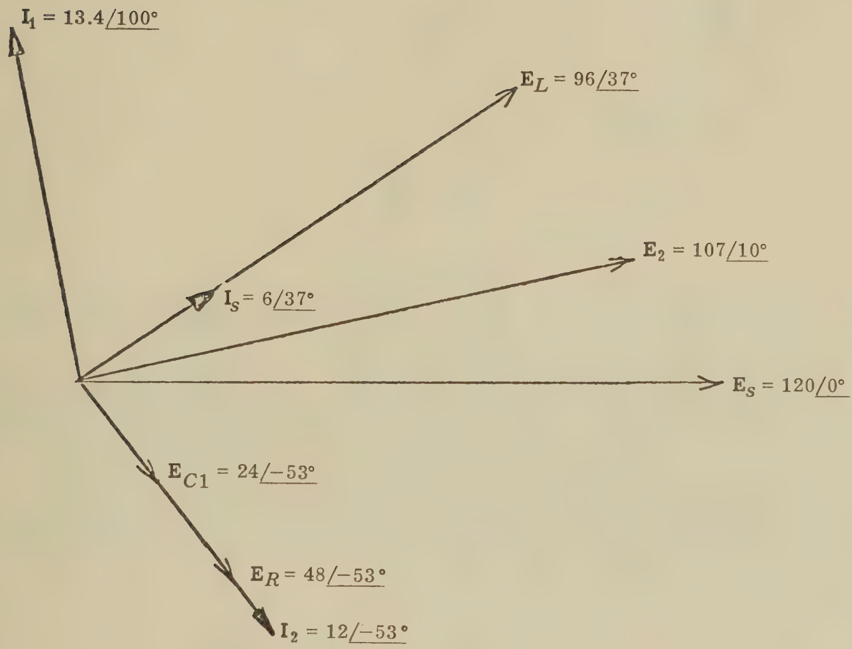

$\mathbf{I}_1 = 13.4\underline{/100°}$
$\mathbf{E}_L = 96\underline{/37°}$
$\mathbf{E}_2 = 107\underline{/10°}$
$\mathbf{I}_s = 6\underline{/37°}$
$\mathbf{E}_s = 120\underline{/0°}$
$\mathbf{E}_{C1} = 24\underline{/-53°}$
$\mathbf{E}_R = 48\underline{/-53°}$
$\mathbf{I}_2 = 12\underline{/-53°}$

Fig. 22

$P_L = 0$. **(5)** 50 watts. **(7)** $I_{ave} = 0.272 I_m$ amp, $I_{eff} = 0.477 I_m$ amp. **(9)** 125 ohms, $X = 111.8$ ohms, 0.894 amp. **(11)** 200 μf. **(13)** Proof. **(15)** 16 ohms, 4 ohms. **(17)** **(a)** 20.1 μf. **(b)** 26.9 μf. **(c)** 51.2 μf. **(19)** **(a)** Passive, resistive, 150 watts. **(b)** Passive, resistive, 3 watts. **(c)** Passive, capacitive, 3.83 watts. **(d)** Passive, capacitive, 1 watt. **(e)** Active, capacitive, 7 watts. **(f)** Passive, inductive, 0 watt. **(20)** **(a)** $\mathbf{P}_s = 2.67 - j4$ mva, $\mathbf{P}_C = -j5.78$ mva, $\mathbf{P}_L = j1.78$ mva, $\mathbf{P}_R = 2.67$ mwatts. **(b)** $\mathbf{P}_{s,\text{left}} = -2.5 - j5$ va, $\mathbf{P}_{s,\text{right}} = 7.5 - j10$ va, $\mathbf{P}_{C,\text{left}} = -j2.5$ va, $\mathbf{P}_{C,\text{right}} = -j12.5$ va, $\mathbf{P}_R = 5$ watts. **(22)** 250 watts after reversing. **(23)** **(a)** $6 + j8$ ohms. **(b)** From left to right: $2 \sin 10^5 t$ amp, 100μhenrys, 1 μf, 10 ohms, 10 ohms, i_L, 100 μhenrys.

(c) $0.4 - j0.8$ amp, $0.894 \cos (10^5 t - 63.4^\circ)$ amp. (d) $10\underline{/0^\circ}$ volts in series with 5 ohms. (e) $P_{\text{orig.}} = 12$ watts, $P_{\text{Thév.}} = 2$ watts. (f) $\mathbf{P} = j4$ va. (g) See Fig. 23. (h) 4 vars. (25) (a) 70.7 volts. (b) 0. (c) 25 watts. (d) $25 + j25$ va. (e) 25 watts. (f) 50 watts.

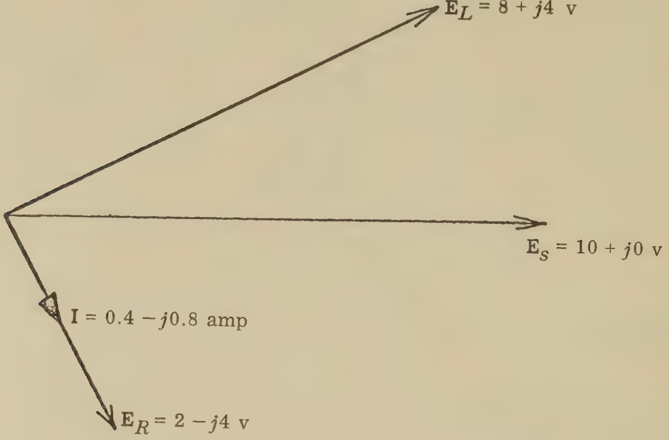

$\mathbf{E}_L = 8 + j4$ v
$\mathbf{E}_s = 10 + j0$ v
$\mathbf{I} = 0.4 - j0.8$ amp
$\mathbf{E}_R = 2 - j4$ v

Fig. 23

Chapter 13

(3) −1 amp. (4) $0.05\epsilon^{-t/1000}$ amp. (6) $0.25\epsilon^{-1000t}$ amp. (8) −149 volts and −7.45 volts. (9) See Fig. 24. (10) (b) $1.053\epsilon^{-2t} + 0.328\epsilon^{2t}$ amp. (c) Same as (b). (11) $0.6 \cos (5t + 53.1^\circ) - 2\epsilon^{-4t}$ amp. (13) $i = 10(\epsilon^{-t/4} - \epsilon^{-t/2})u(t)$ amp. (15) (a) $-3\epsilon^{-2t}$ amp. (b) $(-3\epsilon^{-2t} + 10\epsilon^{-4.8t})u(t)$ amp. (16) (a) See Fig. 25. (17) See Fig. 26. (18) (a) Pole at $\sigma = -0.833$, zero at infinity. (b) Pole at origin and $\sigma = -1.75$, zeros at −0.5 and infinity. (c) Poles at $\sigma = -5/3$ and −5, zeros at −20/3 and infinity. (21) (a) See Fig. 27. (b) See Fig. 28. (22) See Fig. 29. (23) (a) An inductive path between the terminals must be present. (b) There must be a capacitor in every path between the terminals. (c) A capacitive path between the terminals must be present. (d) There must be an inductor in

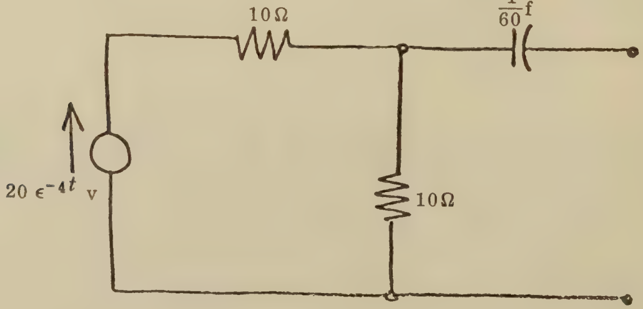


Fig. 24

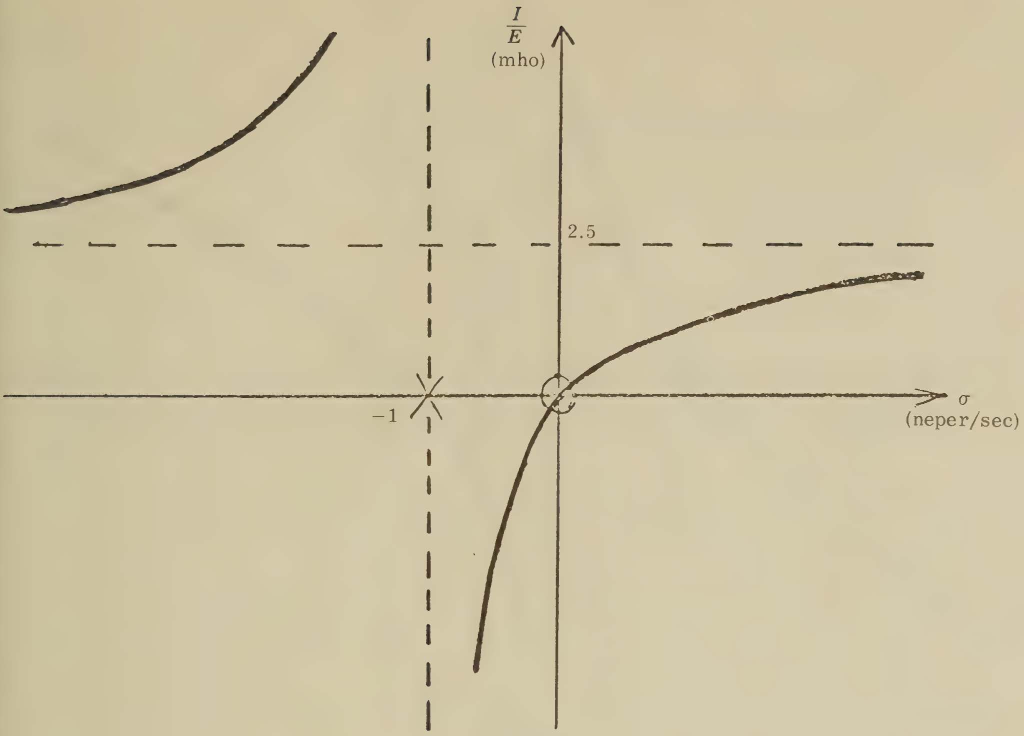


Fig. 25

every path between the terminals. **(25)** **(a)** $|\mathbf{Z}| = \sqrt{(R^4 + 4\omega^2 L^2 R^2)/(R^2 + \omega^2 L^2)}$. **(b)** See Fig. 30. **(26)** See Fig. 31.

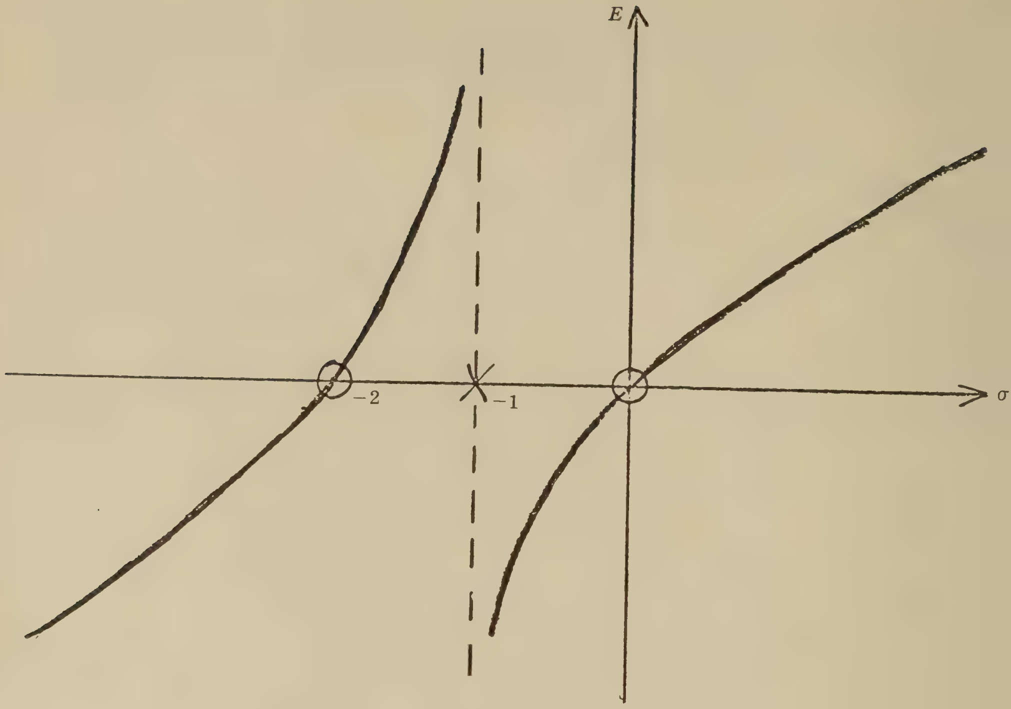


Fig. 26

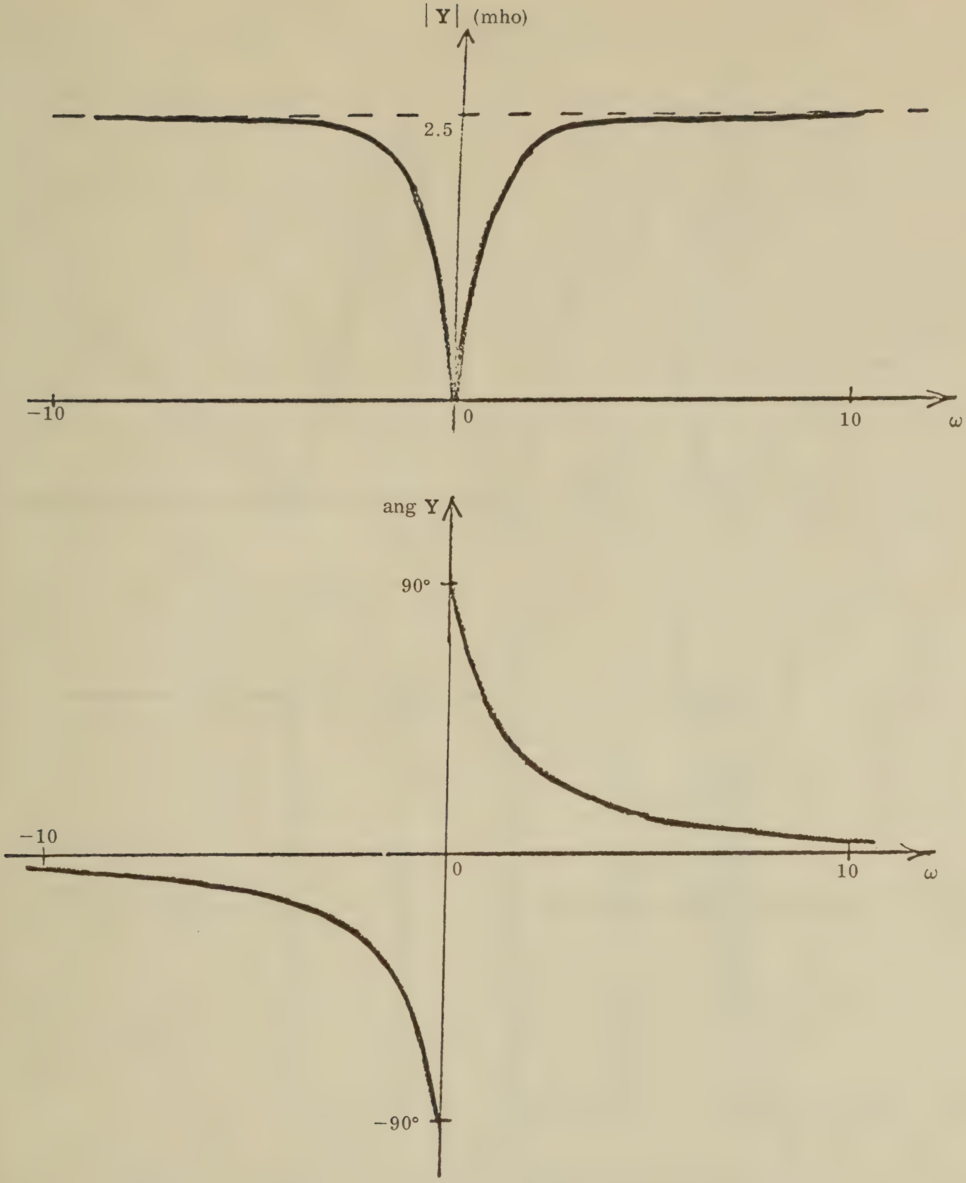


Fig. 27

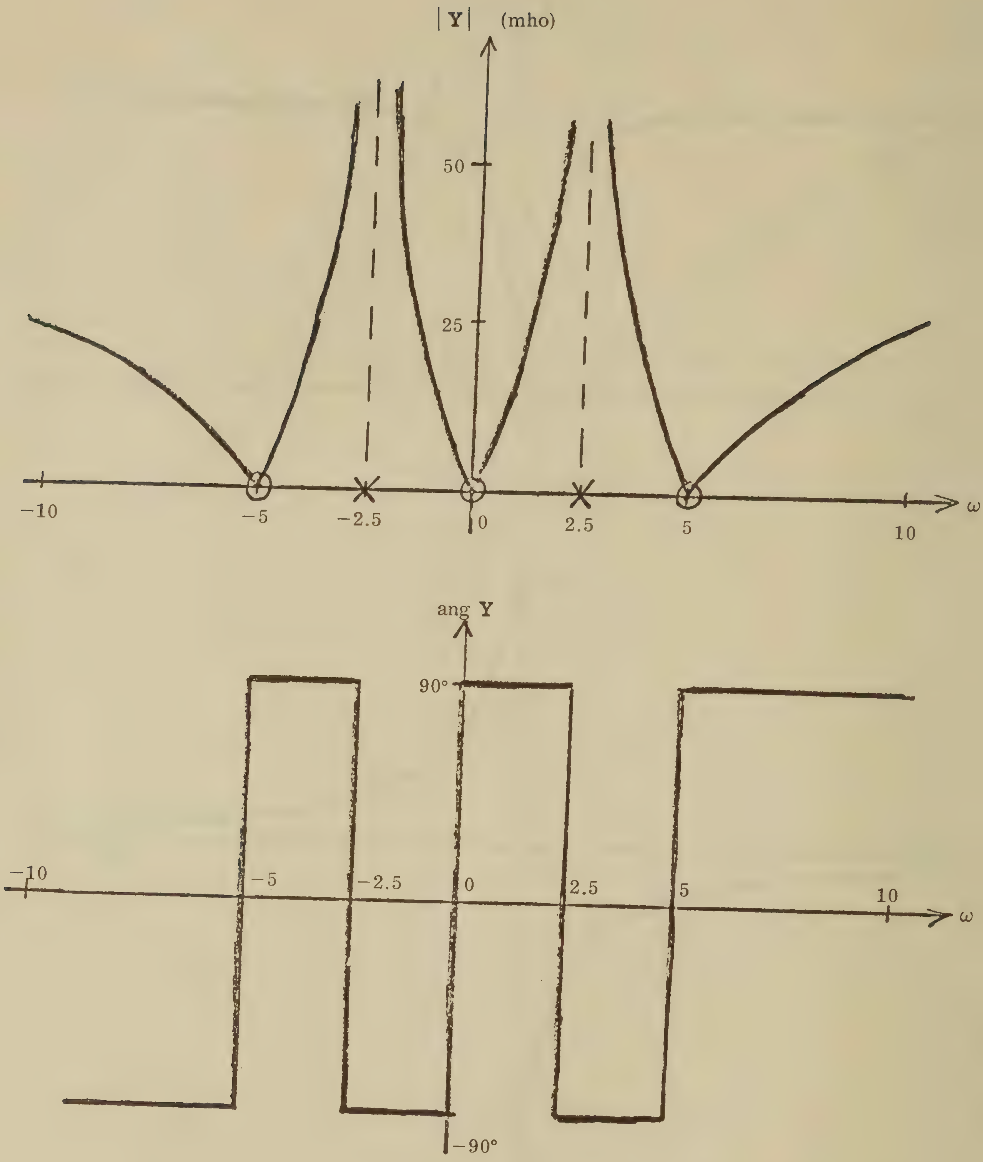


Fig. 28

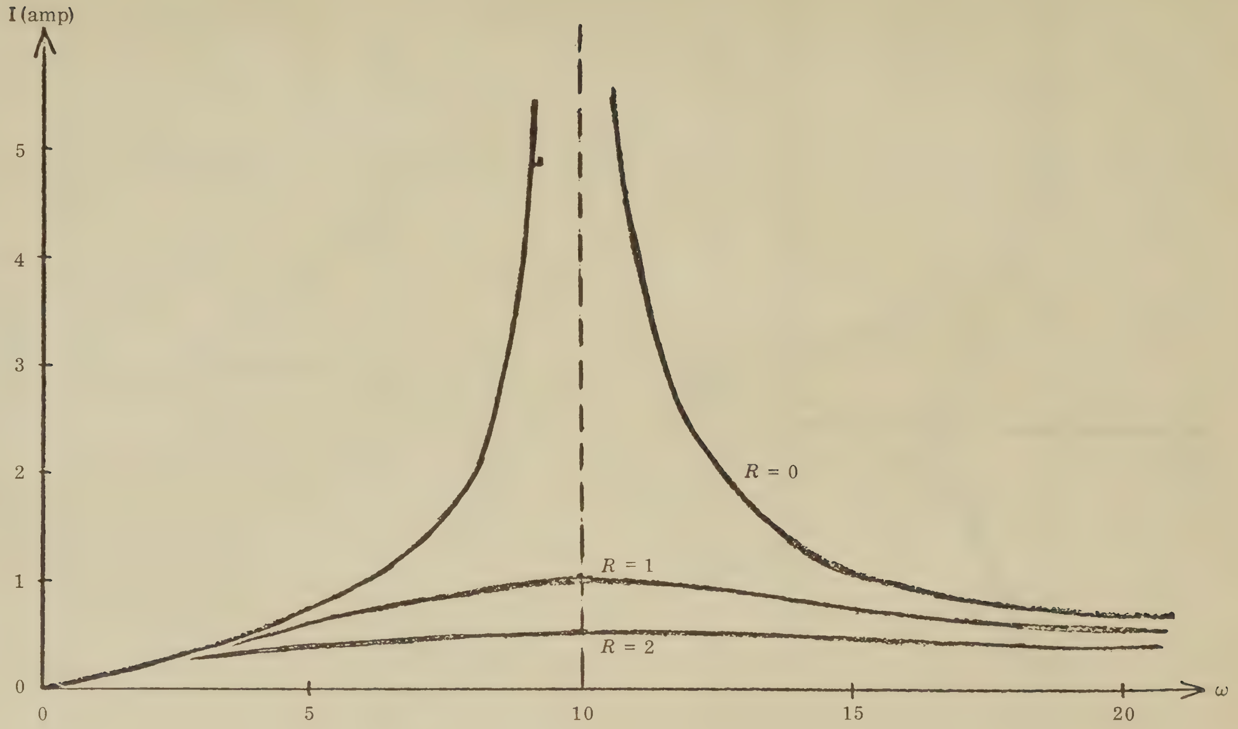


Fig. 29

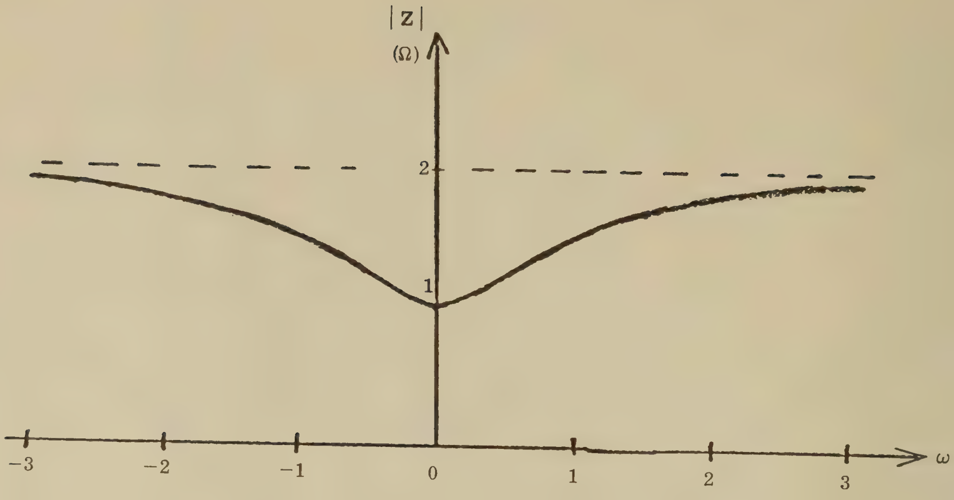


Fig. 30

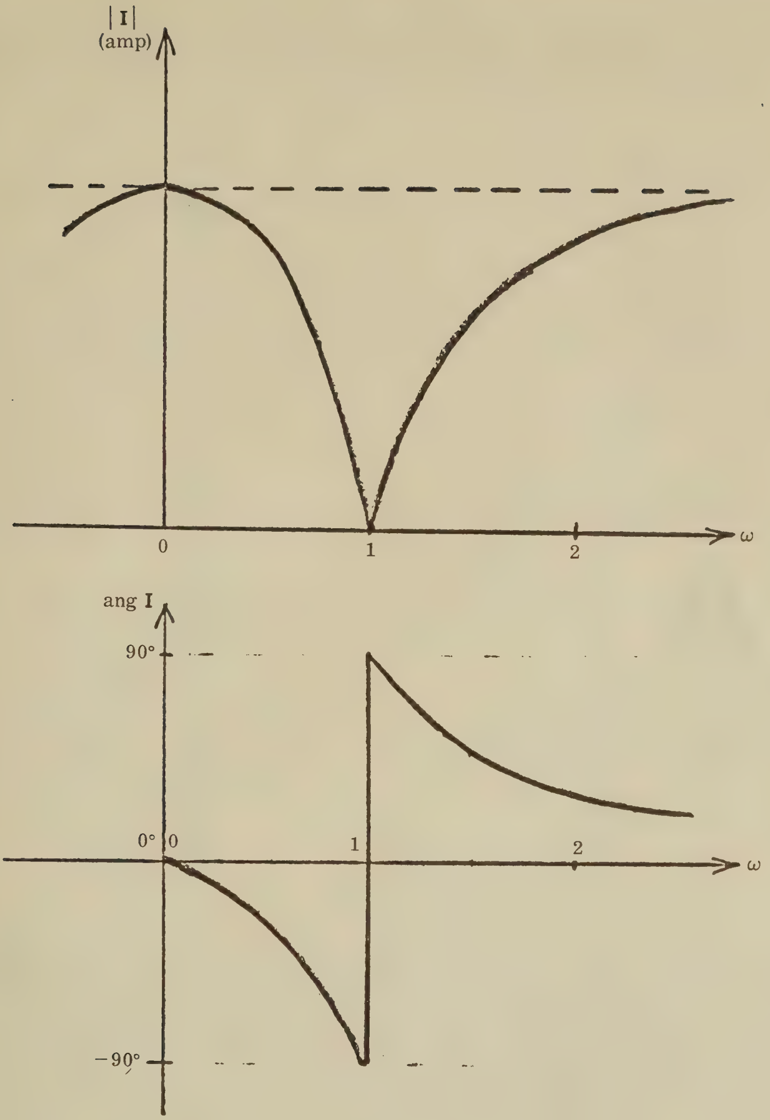


Fig. 31

Chapter 14

(2) **(a)** $3\epsilon^{-100t}\cos 1000t$ amp. **(b)** $20.1\epsilon^{-100t}\cos(1000t + 95.7°)$ amp. **(c)** $1.414\epsilon^{-100t} \times \cos(1000t + 45°)$ amp. **(3)** $e = 5.96\epsilon^{-2t}\epsilon^{j(4t - 33.4°)}$. **(6)** $i = 14.14\epsilon^{-10^5 t}\cos(10^5 t + 135°)$. **(8)** **(a)** Pole at $\mathbf{s} = \infty$, zero at $\mathbf{s} = -2000$. **(b)** Poles at $s = \pm j1$, zeros at $\mathbf{s} = -0.268, -3.732$. **(c)** Poles at $s = -5, -20$, zeros at $\mathbf{s} = \pm j10$. **(9)** **(a)** Pole at $\mathbf{s} = 0$, zero at $\mathbf{s} = -0.2$. **(b)** Poles at $\mathbf{s} = 0, -4$, zeros at $\mathbf{s} = -1.333, \infty$. **(c)** Poles at $\mathbf{s} = 0, -4$, zeros at $\mathbf{s} = -1, -6$. **(e)** Poles at $\mathbf{s} = -1.5 \pm j1.658, \infty$, zeros at

$\mathbf{s} = 0, -3 \pm j1$. (11) (a) $e_1 = 6\epsilon^{-0.1t} \sin 2t$. (b) $e_2 = 60\epsilon^{-0.1t} \cos(2t + 90°)$. (c) $e_{of} = -3\epsilon^{-0.1t} \cos 2t$. (d) Proof. (13) See Fig. 32. (14) (a) $\mathbf{E}_{out}/\mathbf{E} = 4/(\mathbf{s}^2 + 4)$. See Fig. 33*a*. (b) $\mathbf{E}_{out}/\mathbf{E} = 5/(\mathbf{s} + 5)$. See Fig. 33*b*. (16) (a) 26.6°. (b) $\mathbf{Y}(\mathbf{s}) = \frac{1}{2}(\mathbf{s}+3)/(\mathbf{s}+1)$.

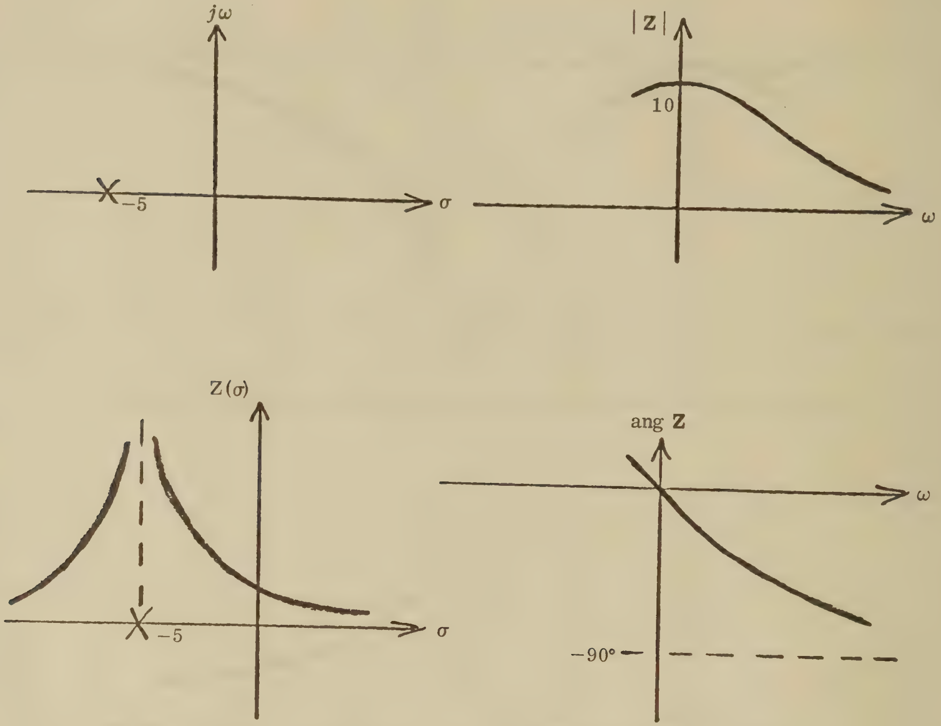
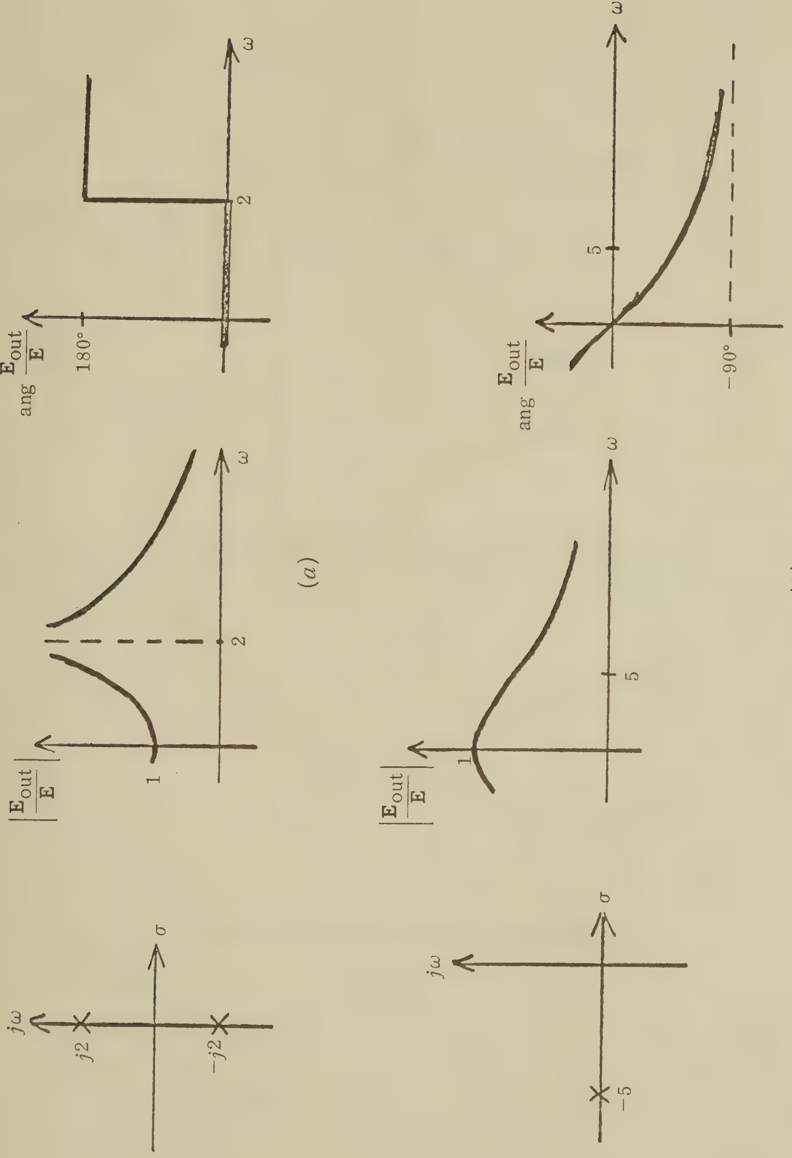


Fig. 32

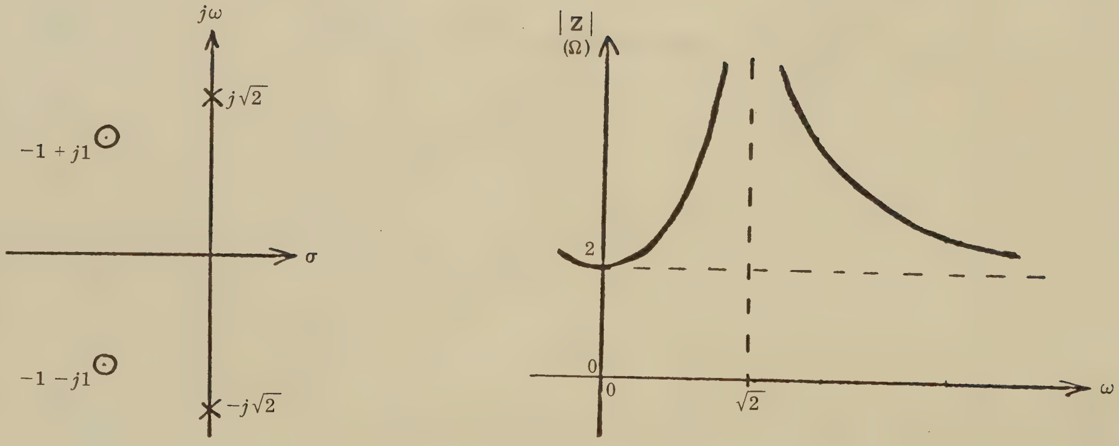
(18) (a) 0.667 ohm. (b) $2 + j4$ ohms. (c) $4 + j0$ ohms. (d) Poles at $\mathbf{s} = \pm j1.414$, zeros at $-1 \pm j1$. (e) See Fig. 34*a*. (f) See Fig. 34*b*. (19) See Fig. 35. (20) See Fig. 36. (21) (b) $\mathbf{Z}(\mathbf{s}) = \mathbf{s} + 4 + 13/\mathbf{s}$; series combination of 1 henry, 4 ohms, and 1/13 farad. (22) (a) $\mathbf{Z}(\mathbf{s}) = K(\mathbf{s} + 5)/\mathbf{s}$. (b) $K = 5$. (c) See Fig. 37. (d) 5 ohms in series with 0.04 farad. (e) Pole stays fixed; zero at $\sigma = -5$ moves left as R or C decreases, and right as either increases. (23) (b) See Fig. 38. (c) Parallel combination of 4 farads, 1/8 ohm, and 1/404 henry. (24) (a) $E_0/16 + A\epsilon^{-4t}$. (b) $45/4 - 1.25\epsilon^{-4t}$. (c) $e = B\epsilon^{-2t}$. (d) $e = 400\epsilon^{-2t}$. (e) An 8-ohm resistor in series with the parallel combination of an 8-ohm resistor and a 1/16-farad capacitor. (26) $i(t) = 1 + \epsilon^{-0.5t}(-\cos 0.866t + 0.577 \sin 0.866t)$. (28) $e = \epsilon^{-t} + 0.5\epsilon^{-t/2}$. (30) (a) $\mathbf{Z}(\mathbf{s}) = 9(\mathbf{s} + 2)/(\mathbf{s} + 6)$. (b) See Fig. 39. (c) See Fig. 39. (d) See Fig. 39. (e) (*b*) is fast and inaccurate; (*c*) is slow and moderately accurate; (*d*) is slow and accurate. (f) $i = A\epsilon^{-2t}$. (g) $i = \pm 3.33\epsilon^{-2t}$. (h) $i = B\epsilon^{-6t}$. (i) $i = \pm 10\epsilon^{-6t}$. (31) (a) $\mathbf{Z}(\mathbf{s}) = (\mathbf{s} + 1)(\mathbf{s} + 3)/\mathbf{s}(\mathbf{s} + 2)$. (b) See Fig. 40*a*. (c) See Fig. 40*b*. (e) $i = \pm 100(\epsilon^{-t} - \epsilon^{-3t})$.


$j\omega$
$j2$
$-j2$
σ
$\left|\frac{E_{out}}{E}\right|$
1
2
ω
ang $\frac{E_{out}}{E}$
180°
$j\omega$
-5
σ
$\left|\frac{E_{out}}{E}\right|$
1
5
ω
ang $\frac{E_{out}}{E}$
5
−90°
ω

(*a*)

(*b*)

Fig. 33



(*a*)

(*b*)

Fig. 34

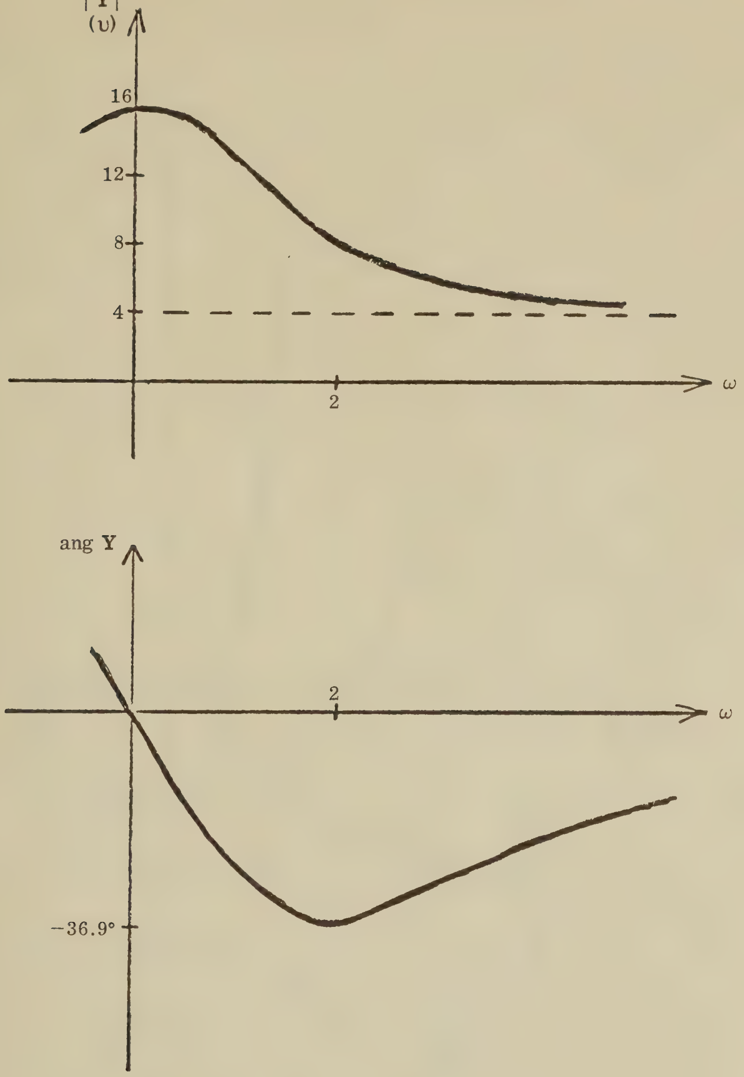


Fig. 35

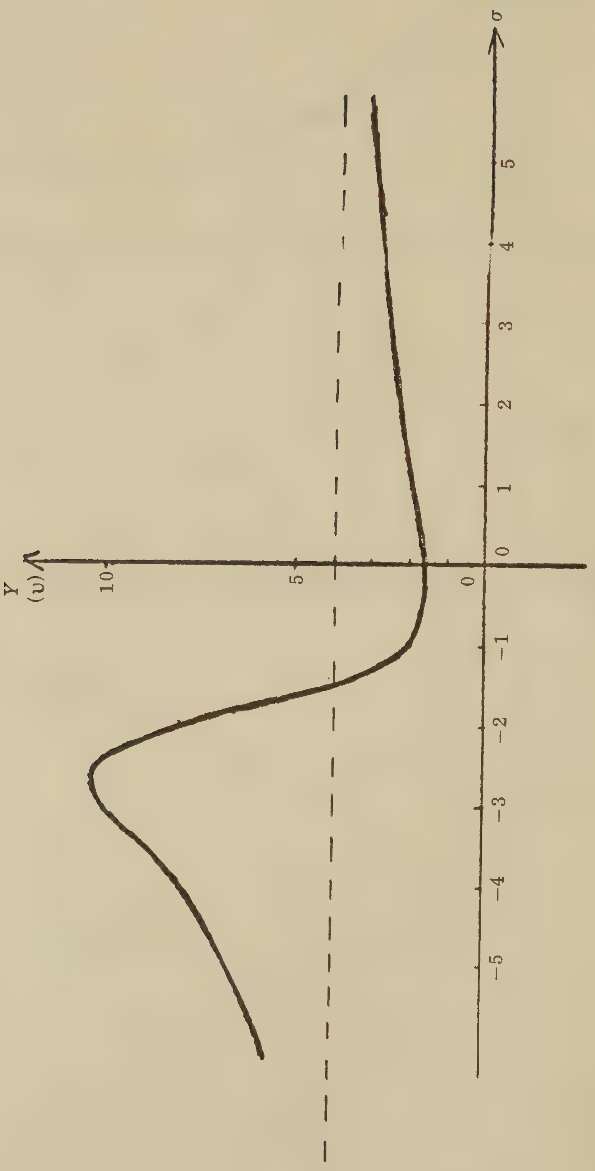


Fig. 36

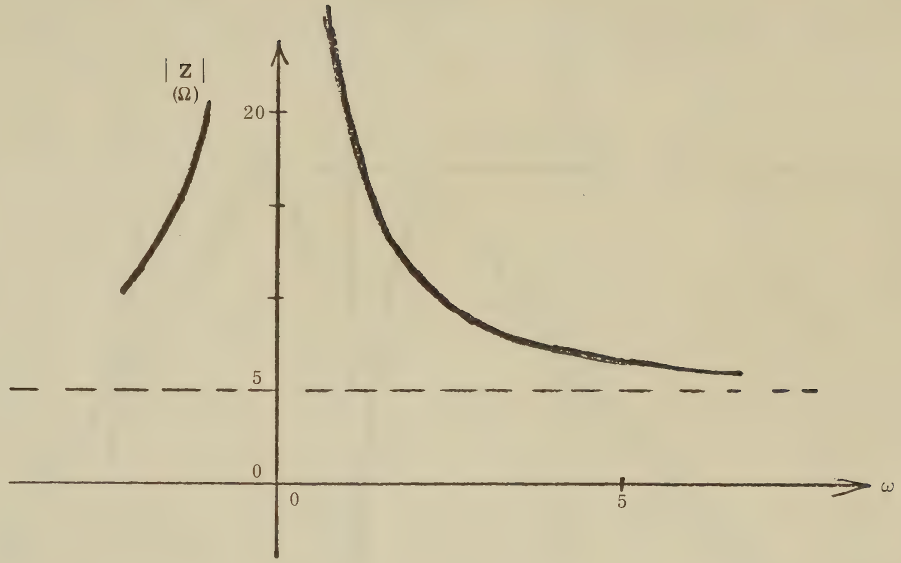


Fig. 37

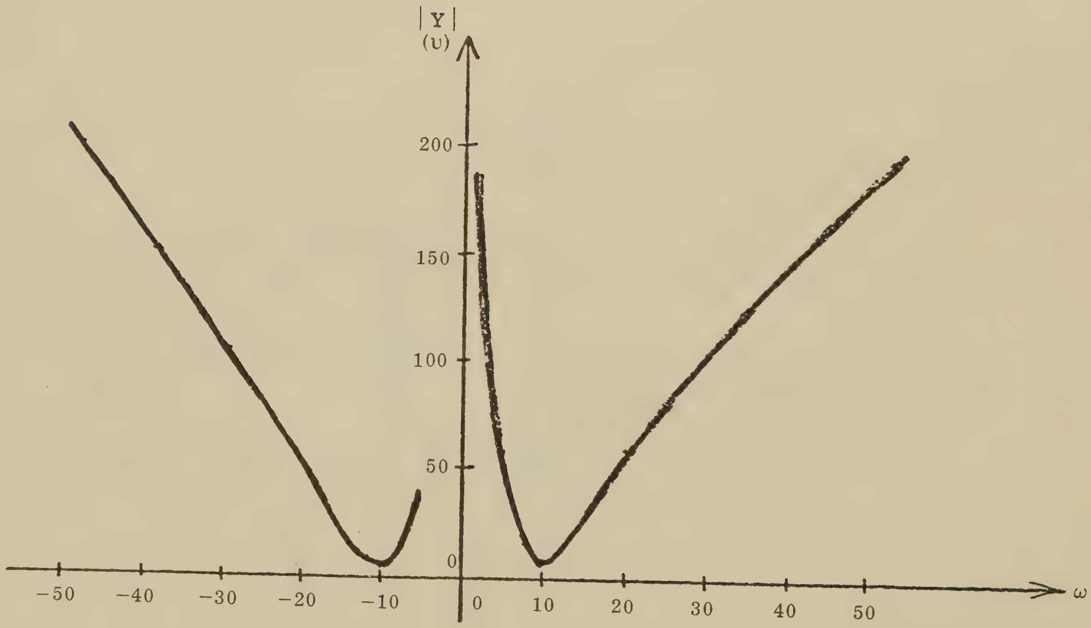
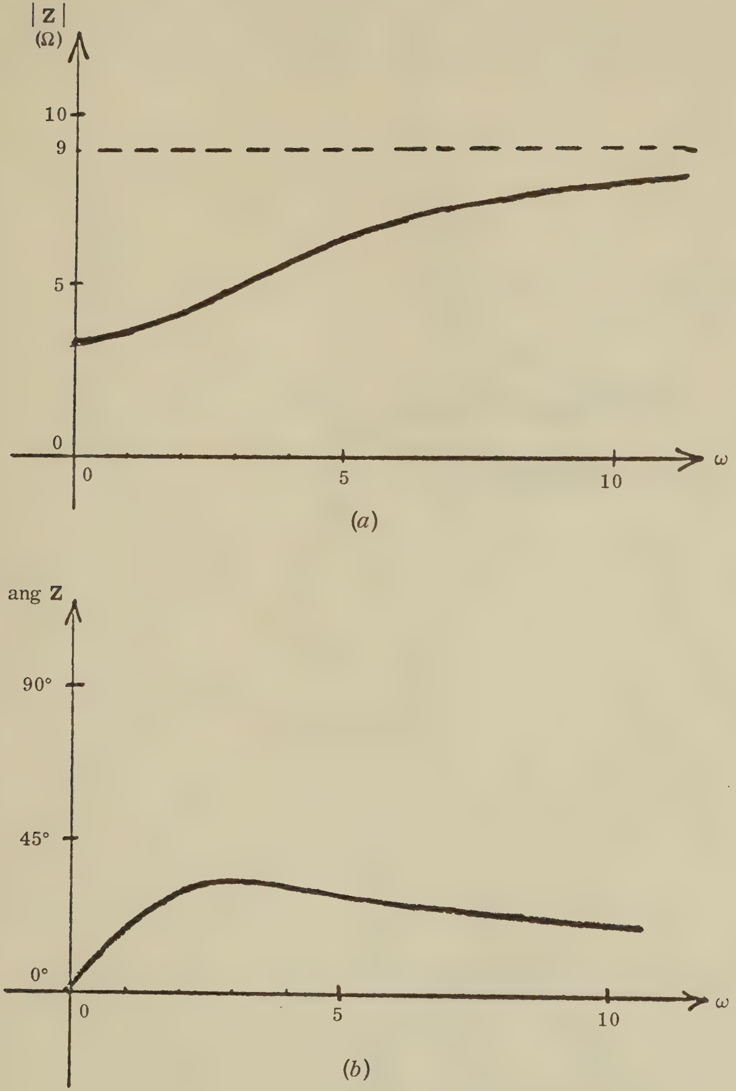


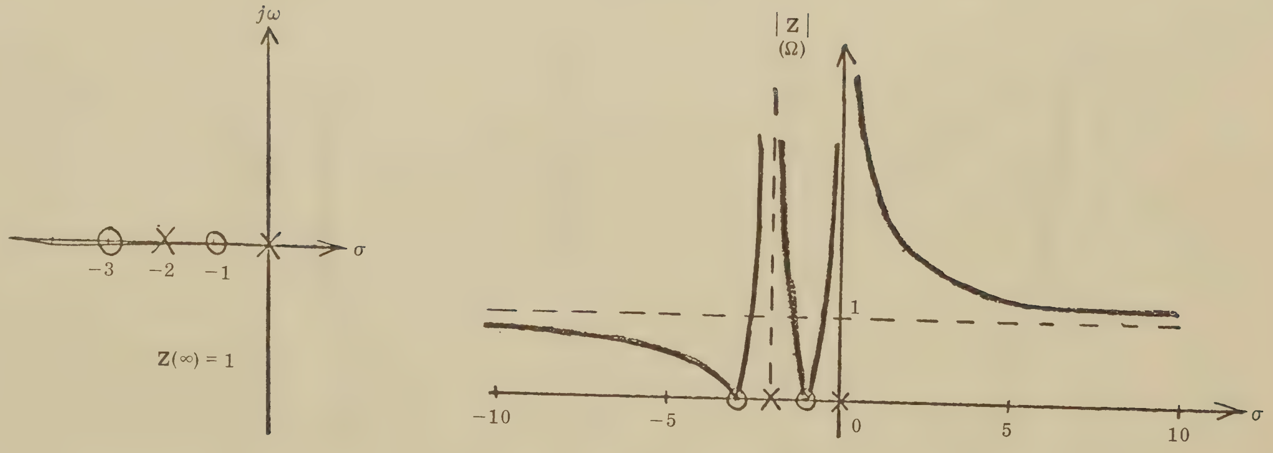
Fig. 38



(a)

(b)

Fig. 39



(a)

(b)

Fig. 40

Chapter 15

(1) (a) See Fig. 41. (b) See Fig. 42. (c) See Fig. 43. (d) See Fig. 44. (3) Proof. (4) Proof. (5) (a) Lower semicircle; left intercept, $2 + j0$; right intercept, $6 + j0$. (b) Upper semicircle; left intercept $2 + j0$; right intercept, $4 + j0$. (7) Upper semicircle; left intercept, $4 + j0$; right intercept, $4.5 + j0$. (9) (a) Circle; $\omega = 0$ at $10 + j0$, $\omega = 9.9$ at $60 + j50$, $\omega = 10$ at $110 + j0$, $\omega = 10.1$ at $60 - j50$. (b) Current source in parallel with 10 mhos and series combination of 100 mhos, 0.2 farad,

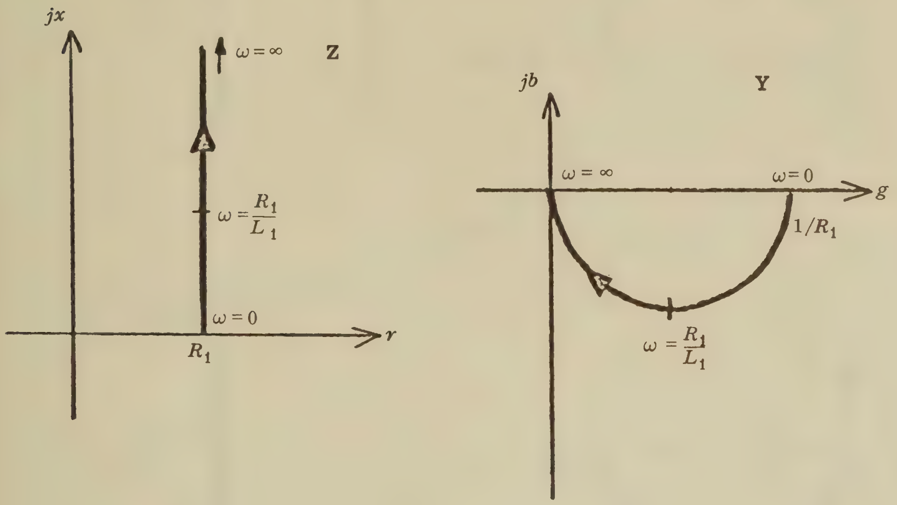


Fig. 41

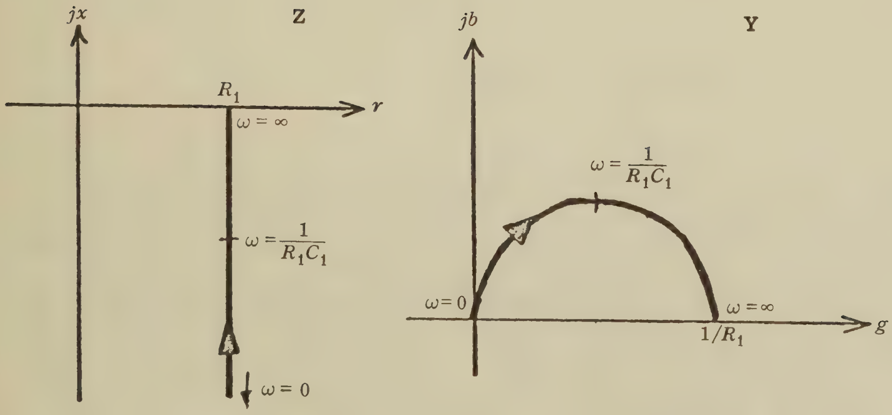


Fig. 42

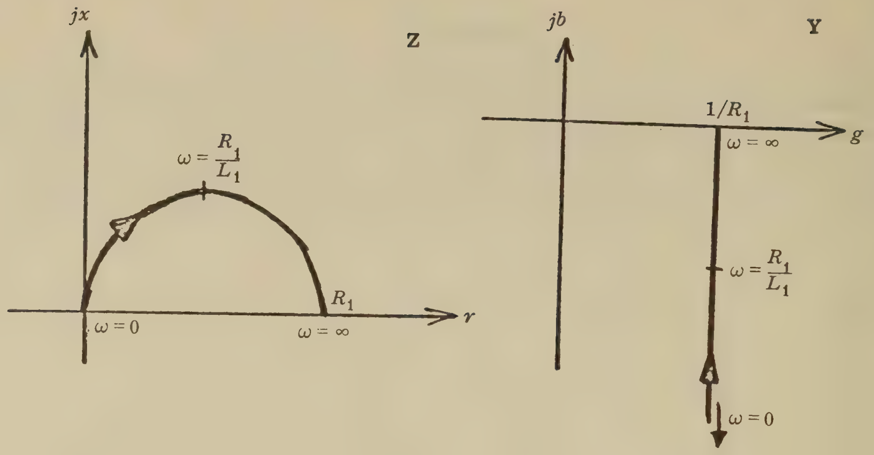


Fig. 43

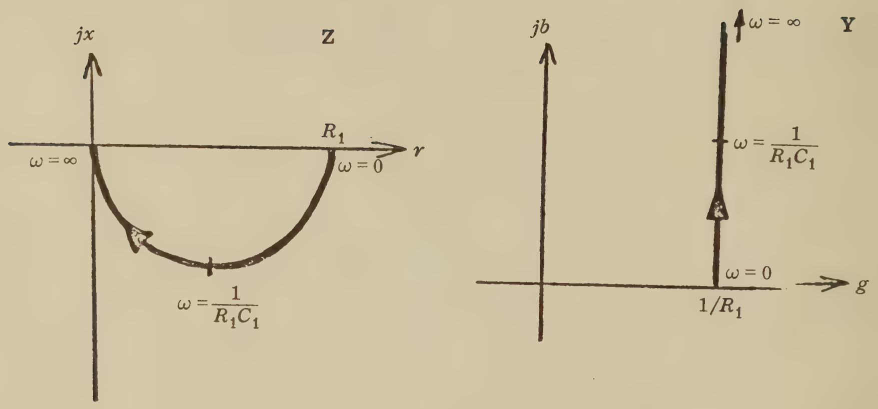
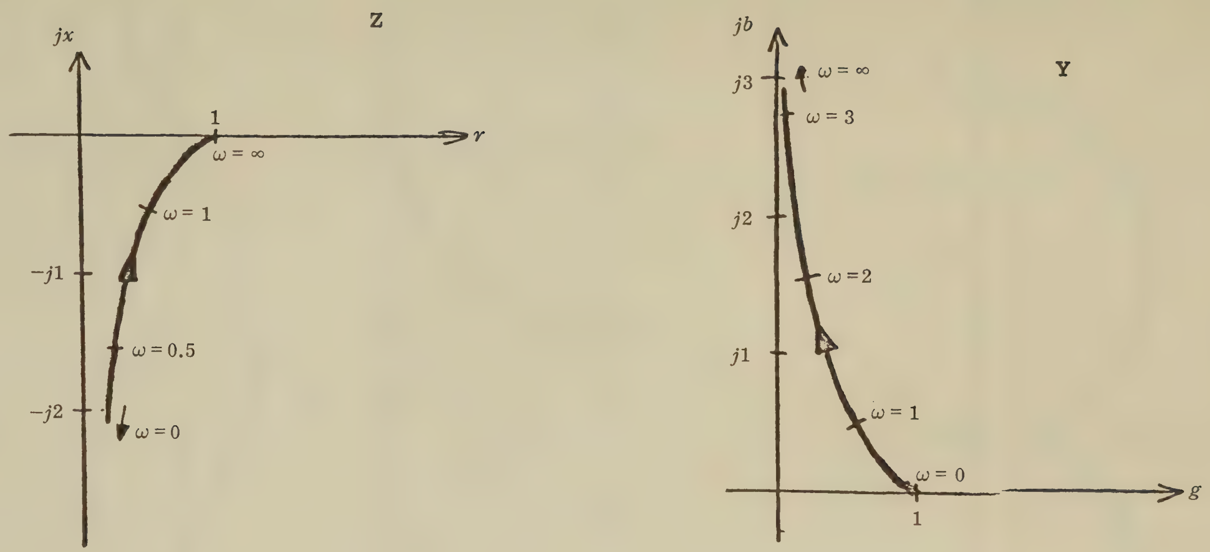


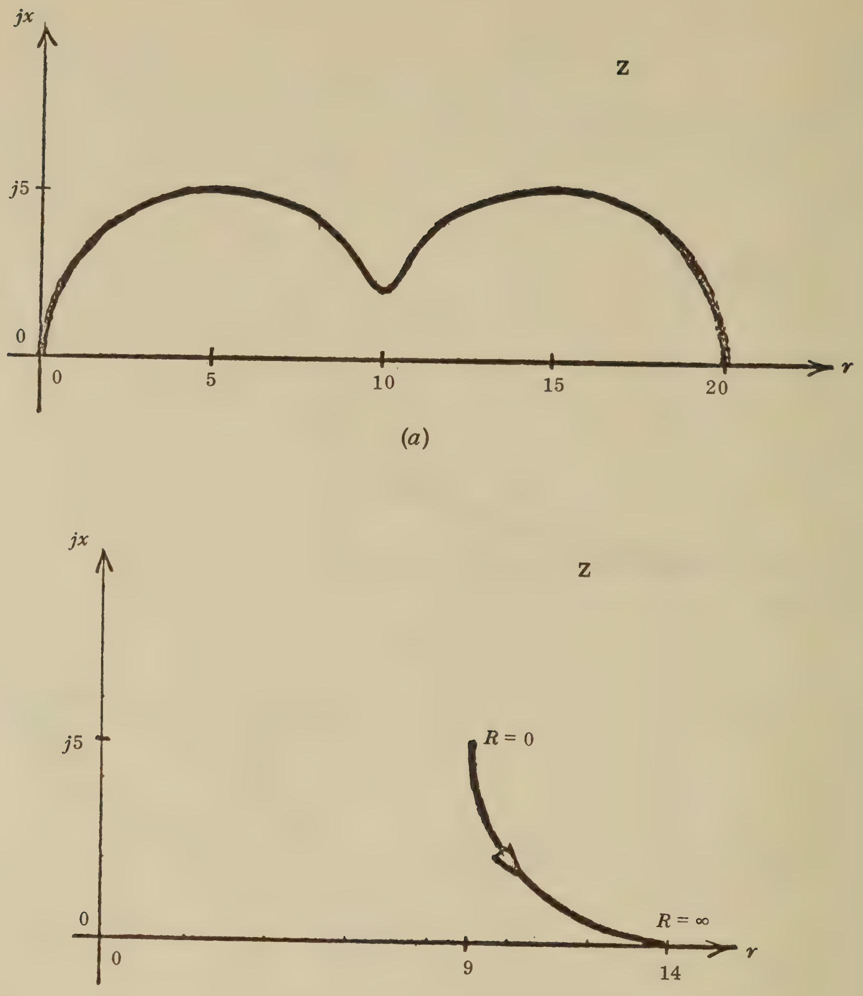
Fig. 44

and 0.05 henry. (c) Circle; $\omega = 0$ at $0.1 + j0$, $\omega = 9.9$ at $(6 - j5)/110$, $\omega = 10$ at $1/110 + j0$, $\omega = 10.1$ at $(6 + j5)/110$. **(10)** (a) Upper semicircle; left intercept, $0.5 + j0$; right intercept, $0.75 + j0$. (b) Upper semicircle; left intercept, $0.5 + j0$; right intercept, $0.75 + j0$. **(11)** (a) Impedance locus is upper semicircle; left intercept at $5 + j0$; right intercept at $15 + j0$. Admittance locus is lower semicircle; left intercept at $0.0667 + j0$; right intercept at $0.2 + j0$. **(12)** 50-ohm resistor in series with 1/80-henry inductor; impedance locus is upper semi-infinite straight line, intercept at $50 + j0$. **(13)** See Fig. 45. **(15)** (a) Upper semicircle, left intercept at $5.66 + j0$, right intercept at $100 + j0$. (b) See Fig. 46*a*. **(17)** See Fig. 46*b*. **(18)** Circle; left intercept, origin, $\omega = 0$ and ∞; right intercept, $1 + j0$, $\omega = \omega_0$. **(20)** Circle; left intercept, origin, $\omega = 0.447$; right intercept, $1 + j0$, $\omega = 0$ and ∞. **(21)** Upper half of vertical semi-infinite straight line, intercept at $5 + j0$. **(23)** Impedance locus is right half of horizontal semi-infinite straight line, intercept at



(a) (b)

Fig. 45



(a)

(b)

Fig. 46

$0 + j\omega L$; admittance locus is right half of circle; upper intercept at origin, $R = \infty$; lower intercept at $-j/\omega L$, $R = 0$. (24) (a) Upper semicircle, left intercept at origin, right intercept at $R + j0$. (b) Right semicircle, upper intercept at $0 + j\omega L$, lower intercept at origin. (c) Upper semicircle, left intercept at origin, right intercept at $R + j0$. (25) (a) Lower semicircle, left intercept at origin, right intercept at $R + j0$. (b) Right semicircle, upper intercept at origin, lower intercept at $0 - j/\omega C$. (c) Lower semicircle, left intercept at origin, right intercept at $R + j0$. (26) (a) See Fig. 47. (27) Right semicircle; upper intercept, $0 + j1$; lower intercept, origin. (29) (a) 6 volts. (b) 2 amp. (c) $-j4$ amp. (d) $j4$ amp. (e) 6 watts. (f) 2 $\sin^2 6t$ joules. (g) 2 $\cos^2 6t$ joules. (h) 2. (i) 2. (31) $w(0) = \frac{1}{2} CE_0^2$; $w(2\pi/\omega_0) = \frac{1}{2} CE_0^2 \epsilon^{-2\pi/Q_0}$; $Q_0 = \omega_0 RC$. (33) 1570 radians/sec; 5 sec^{-1}; 1570 radians/

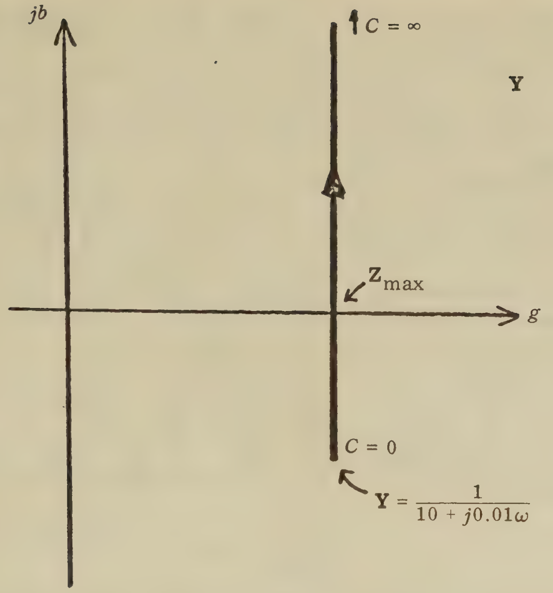


Fig. 47

sec; 157; a few cps flat, since $f_0 = 250$ cps, and $f_{\text{middle } C} = 256$ cps. **(35)** (a) 100, $-j1$ ma. (b) 1 μwatt. (c) Losses increase 2%, Q_0 drops 2%. **(37)** See Fig. 48. **(38)** Proofs. **(39)** 1 ohm at 10 radians/sec; 10 volts at 10 radians/sec; 10 amp at 10 radians/sec; 20.66 amp at 10.68 radians/sec; 20.66 amp at 9.36 radians/sec. **(41)** 10,000 ohms, 1592 pf, 15.92 μhenrys. **(43)** 0.002 mho at 60 cps, $0.00283\underline{/-45^\circ}$ mho at 58 cps, $0.00283\underline{/45^\circ}$ mho at 62 cps, $0.00447\underline{/-63.4^\circ}$ at 56 cps, $0.00447\underline{/63.4^\circ}$ mho at 64 cps, $0.00632\underline{/-71.6^\circ}$ mho at 54 cps, $0.00632\underline{/71.6^\circ}$ mho at 66 cps. **(44)** (a) $R_2 = R_1$, $L_2 = \frac{1}{2}L_1$, $C_2 = \frac{1}{2}C_1$. (b) $R_2 = R_1$, $L_2 = \frac{1}{2}L_1$, $C_2 = 2C_1$. (c) $R_2 = \frac{1}{2}R_1$, $L_2 = \frac{1}{2}L_1$, $C_2 = 2C_1$. (d) Impossible. **(46)** (a) $\omega_0 = 100$. (b) $Q_0 = 50$. (c) 1000 ohms, 500 μfarads, and 0.2 henry in parallel. **(48)** (a) 500. (b) 79.6. (c) 0.1. **(50)** (a) Poles

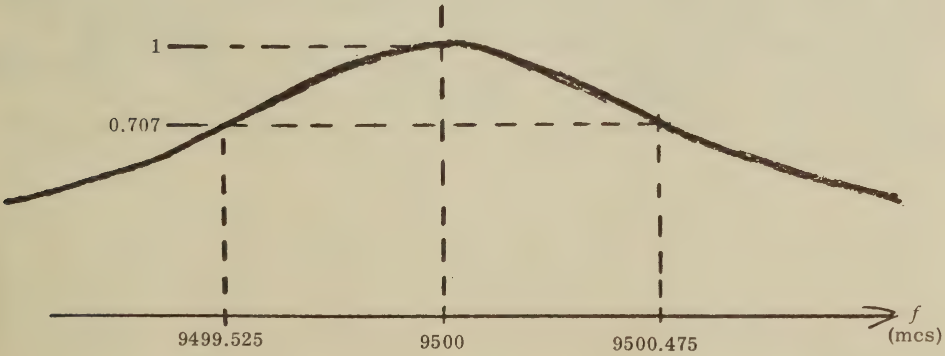


Fig. 48

at $s = -1.5 \pm j100$, zeros at -2 and $-10{,}000$. (b) $\omega = 100$, approximately. (52) 4 ma, 4.8 volts. (54) (a) 0.1 μfarad. (b) 1.25 ohms. (c) $3.25\angle{-67.4^\circ}$ ohms. (56) (a) 10 ohms, 100 radians/sec, 95 and 105 radians/sec. (b) Circle; left intercept, origin, $\omega = 0$ and ∞; right intercept, 0.1 mho, $\omega_0 = 100$. (58) $2000\angle{60^\circ}$ ohms. (60) (a) Proof. (b) Proof. (61) (b) 10^6 ohms and 100 pf; 200 ohms and 50 pf; 5000 ohms and 2 henrys; 250 ohms and 10 henrys. (c) Yes; no; yes; no. (62) (a) Yes, 50. (b) Yes, 40. (c) Yes, 66.7. (d) Yes, 47.1. (e) Yes, 50. (f) Yes, 40. (63) For frequency in kiloradians/sec and voltage in volts: 9.8 at 9.5 and 10.5, 12.1 at 9.6 and 10.4, 15.8 at 9.7 and 10.3, 22.4 at 9.8 and 10.2, 35.4 at 9.9 and 10.1, 50 at 10. (64) Proof. (66) $\mathbf{Z}(s) = 2$; bandwidth is infinite. (68) 0.2 radians/sec. (69) (b) 0.05 μfarad, 600 ohms, 200 mhenrys, 10,000 ohms. (70) (b) 0.01 μfarad, 30 ohms, 0.1 mhenry, 500 ohms. (71) (b) 0.001 μfarad, 1500 ohms, 25 mhenrys, 25,000 ohms. (72) (a) $\mathbf{Z}_1 = 20(s + 1)$; $\mathbf{Z}_2 = 20\,(10s^2 + 70s + 60)/(s^2 + 4s)$; $\mathbf{Z}_3 = 20(s^3 + 6s^2 + 10s)/(s^2 + 3s + 5)$. (b) $\mathbf{Z}_1 = 0.1(s + 10)$; $\mathbf{Z}_2 = 10\,(s^2 + 70s + 600)/(s^2 + 40s)$; $\mathbf{Z}_3 = 0.1(s^3 + 60s^2 + 1000s)/(s^2 + 30s + 500)$. (c) $\mathbf{Z}_1 = 2.5(s + 20)$; $\mathbf{Z}_2 = 500\,(s^2 + 140s + 2400)/(s^2 + 80s)$; $\mathbf{Z}_3 = 2.5\,(s^3 + 120s^2 + 4000s)/(s^2 + 60s + 2000)$. (73) (a) $2.5/(s + 12.5)$. (b) $2.5/(s + 12.5)$. (c) $25/(s + 125)$. (d) No for magnitude scaling, yes for frequency scaling.

Chapter 16

(1) (a) Both upper terminals may be dotted, or both lower terminals may be dotted. (b) Both upper terminals may be dotted, or both lower terminals may be dotted. (3) $e_{CD} = 2(di/dt)$; $e_{AD} = 3(di/dt)$; $e_{AC} = (di/dt)$. (5) Proof. (6) (a) $\pm(66.1 - j19.8)$ amp. (b) $\mathbf{I}_1/\mathbf{I}_S = (\frac{3600}{19})s/(s + 0.826)(s + 25.5)$; poles at $s = -0.826$ and -25.5, zeros at $s = 0$ and ∞. (c) s-plane plot same as Fig. 16-6; plot of magnitude same as Fig. 16-7. (7) (a) $L_1 + L_2 + 2M$. (c) $(L_1L_2 - M^2)/(L_1 + L_2 - 2M)$. (e) $(L_1L_2 - M^2)/L_2$. (f) $(L_1L_2 - M^2)/L_2$. (8) $(5 + 4s)\mathbf{I}_1 - (3 + 3s)\mathbf{I}_2 - s\mathbf{I}_3 = \mathbf{E}_S$; $-(3 + 3s)\mathbf{I}_1 + (9 + 7s + \frac{10}{s}\,\mathbf{I}_2 - (6 + 4s)\mathbf{I}_3 = 0$; $-s\mathbf{I}_1 - (6 + 4s)\mathbf{I}_2 + (13 + 5s)\mathbf{I}_3 = 0$. (10) $i_1R + (L_1 + L_2 - 2M)di_1/dt + (M - L_2) \times di_2/dt = e_S$; $(M - L_2)di_1/dt + L_2di_2/dt + \frac{1}{C}\int_0^t i_2dt + e_C(0) = 0$. (11) (a) $L_{sa} = L_1 + L_2 + 2k\sqrt{L_1L_2}$; $L_{so} = L_1 + L_2 - 2k\sqrt{L_1L_2}$; $L_{pa} = L_1L_2(1 - k^2)/(L_1 + L_2 - 2k\sqrt{L_1L_2}$; $L_{po} = L_1L_2(1 - k^2)/(L_1 + L_2 + 2k\sqrt{L_1L_2}$. (b) $L_{sa} \doteq L_1 + L_2$; $L_{so} \doteq L_1 + L_2$; $L_{pa} \doteq L_1L_2/(L_1 + L_2)$; $L_{po} \doteq L_1L_2/(L_1 + L_2)$. (c) $L_{sa} \doteq (\sqrt{L_1} + \sqrt{L_2})^2$; $L_{so} \doteq (\sqrt{L_1} - \sqrt{L_2})^2$; $L_{pa} \doteq 0$ unless $L_1 \doteq L_2$; $L_{po} \doteq 0$. (12) $M = \frac{1}{4}(L_{sa} - L_{so})$; inaccurate if $L_{sa} \doteq L_{so}$, or k is small; method is also incapable of yielding three-figure accuracy desired when $k \doteq 1$. (13) $i(t) = 2.5 + 2.5(\epsilon^{-2t} - 1)u(t)$; $i_L(t) = 30(1 - \epsilon^{-2t})u(t)$; see Fig. 49. (14) (b) 10 mhenrys. (c) 19 mhenrys. (d) 0.506. (e) At D. (f) $32\angle{180^\circ}$ volts. (g) $10\angle{90^\circ}$ volts. (i) $10\angle{180^\circ}$ volts. (15) $i(t) = 10(1 - \epsilon^{-t/8.5}\,u(t)$; $e_x(t) = -8.24\epsilon^{-t/8.5}u(t)$ (16) (b) 10.0 henrys. (c) 9.62 henrys. (17) $i_x(t) = -0.294\cos(10t + 11.3^\circ) + 0.288e^{-2t}$. (19) $k = 0.5$; 5 amp. (21) $P_S = 440$ watts; $P_L = 250$ watts. (23) (a) 2. (b) 0. (25) 1.833 kilowatts.

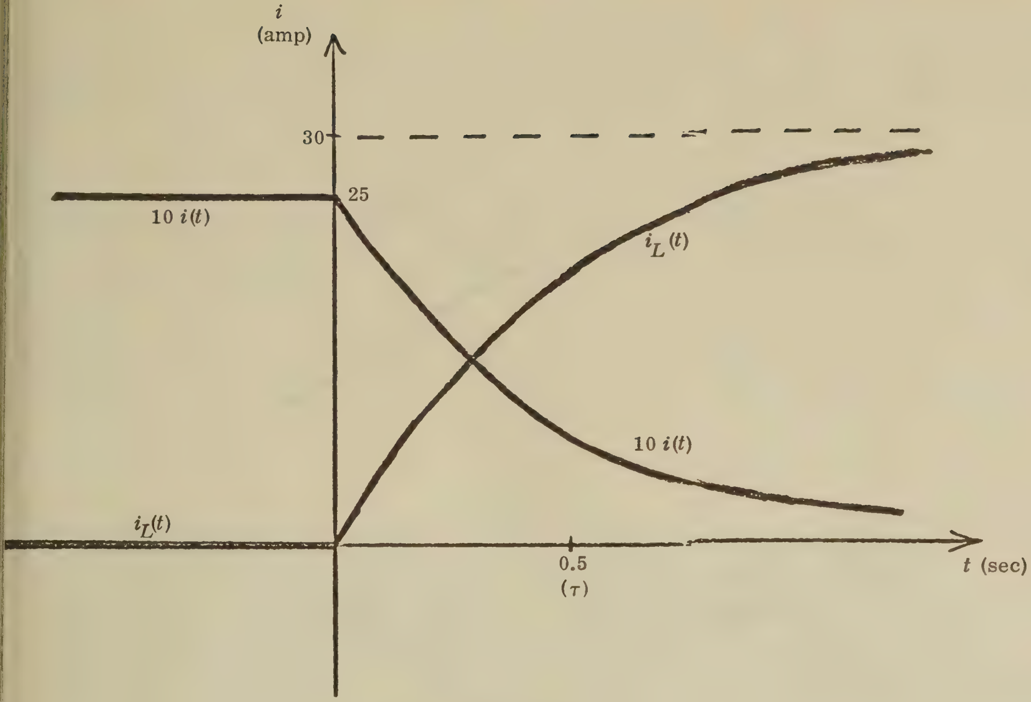


Fig. 49

Chapter 17

(2) Proof. (4) $\mathbf{I}_1 = 6$; $\mathbf{I}_2 = 15$. (6) (a) $\mathbf{y}_{11} = \mathbf{y}_{22} = 1.375$ mhos; $\mathbf{y}_{12} = \mathbf{y}_{21} = -1.125$ mhos. (b) $R_{\text{upper left}} = R_{\text{upper right}} = 0.4$ ohm; $R_{\text{stem}} = 1.8$ ohms. (8) $\mathbf{E}_2/\mathbf{E}_1 = -\mathbf{y}_{21}/(\mathbf{y}_{22} + \mathbf{Y}_L)$; $\mathbf{E}_2/\mathbf{E}_S = \mathbf{Y}_S\mathbf{y}_{21}/[\mathbf{y}_{12}\mathbf{y}_{21} - (\mathbf{y}_{11} + \mathbf{Y}_S)(\mathbf{y}_{22} + \mathbf{Y}_L)]$. (10) Proof. (11) See Fig. 50. (12) No; see parts (*c*), (*d*), and (*e*) of previous problem. (14) $14.7\underline{/0^\circ}$ volts. (16) $\mathbf{h}_{11} = -797$ ohms, $\mathbf{h}_{21} = -51.8$, $\mathbf{h}_{12} = 0.396 \times 10^{-3}$, $\mathbf{h}_{22} = 17.24 \times 10^{-6}$ mho. (17) See Fig. 51. (19) $\mathbf{z}_{12} = 4$ ohms; $\mathbf{h}_{12} = 2/3$; $\mathbf{y}_{12} = -0.286$ mho. (21) (a) $\mathbf{g}_{11} = 0.2$ mho; $\mathbf{g}_{21} = -\mathbf{g}_{12} = 0.6$; $\mathbf{g}_{22} = 1.2$ ohms. (b) $\mathbf{g}_{11} = 0.714$ mho; $\mathbf{g}_{12} = -\mathbf{g}_{21} = 0.428$; $\mathbf{g}_{22} = -0.857$ ohm. (23) (a) 0 volts in series with 7 ohms. (b) 0 volts in series with -0.5 ohm. (25) (a) $\mathbf{E}_2/\mathbf{E}_1 = -g_m r_p R_b/(r_p + R_b)$. (b) $\mathbf{E}_2/\mathbf{E}_1 = g_m r_p R_k/[R_k(r_p g_m + 1) + r_p]$. (26) Proof. (27) (a) Proof. (b) Proof.

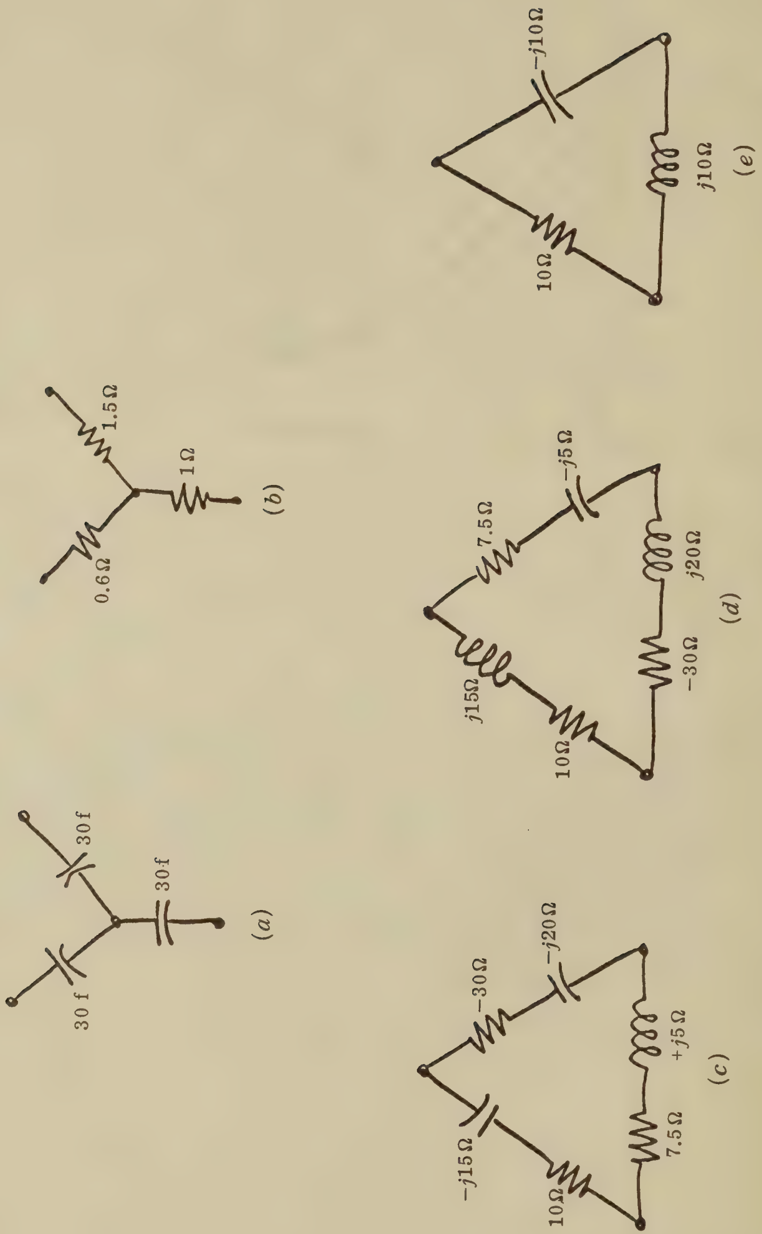

30 f
30 f
30 f
(a)
0.6Ω
1.5Ω
1Ω
(b)
−j15Ω
10Ω
−30Ω
−j20Ω
+j5Ω
7.5Ω
(c)
j15Ω
10Ω
7.5Ω
−j5Ω
j20Ω
−30Ω
(d)
10Ω
−j10Ω
j10Ω
(e)

Fig. 50

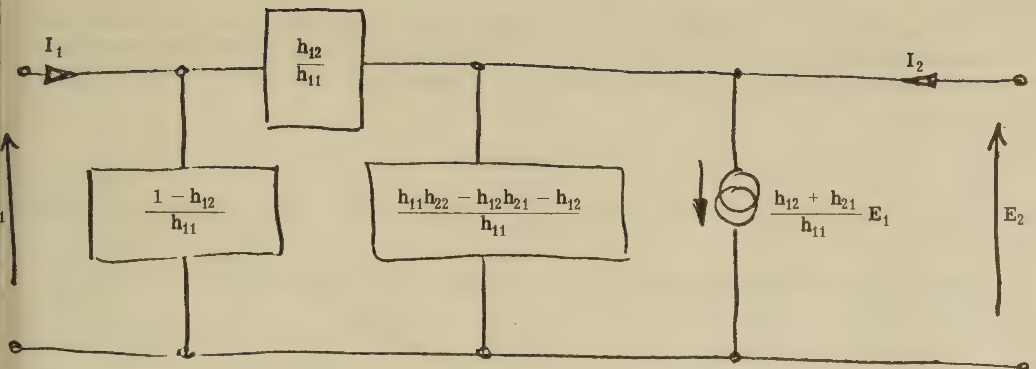

I_1
$\frac{h_{12}}{h_{11}}$
I_2
$\frac{1 - h_{12}}{h_{11}}$
$\frac{h_{11}h_{22} - h_{12}h_{21} - h_{12}}{h_{11}}$
$\frac{h_{12} + h_{21}}{h_{11}} E_1$
E_2

Fig. 51

Chapter 18

(2) (a) $L = 3$, $B = 12$, $N = 10$. (b) $L = 8$, $B = 14$, $N = 7$. (3) (b) 12. (4) (a) Proof. (b) 9; yes. (c) In order to have the eight outside mesh currents all be loop currents, the entire perimeter must be composed of links. But, if the central mesh current is also to be a link current, then one wall of the central mesh must be a link and this would cause one mesh to have two links in it. (6) (a) 5. (b) 8. (c) 4. (d) 4. (e) 4. (7) Use central T as tree; $\mathbf{E}_1 = -1.436$ volts; $\mathbf{E}_2 = -0.347$ volt; $\mathbf{E}_3 = 0.842$ volt. (9) (a) 4. (b) 3. (c) Branches B-C-E. (d) Branches B-A-E, A-E-D, E-D-B, or D-B-A. (e) Branches B-A-E. (11) (a) Six mesh equations; two nodal equations. (13) 0. (15) $\frac{\mathbf{E}_0}{\mathbf{E}_i} = \frac{\mu + r_p/R_G}{\mu + 1 + r_p(1/R_K + 1/R_G)}$. (16) 3.125 amp; upper voltage source may be removed. (18) May select 6-volt, 1-ohm, 3-ohm, and 10-volt branches as tree, assume $\mathbf{I}_x$ through 10-volt branch, and write nodal equations at upper and right nodes.

Chapter 19

(2) $\mathbf{I}_{\text{line}} = 39.0$ amp; $\mathbf{I}_{\text{neutral}} = 0$. (4) $P_{\text{upper line}} = P_{\text{lower line}} = 22.5$ watts; $P_{\text{neutral}} = 0$; $P_{\text{upper load}} = P_{\text{lower load}} = 406$ watts; 94.9%. (5) (a) $100\angle 0^\circ$ volts. (b) $100\angle -90^\circ$ volts. (c) $10\angle 0^\circ$ amp. (d) $5.77\angle 90^\circ$ amp. (e) $11.54\angle 30^\circ$ amp. (f) $10\angle 90^\circ$ amp. (g) $5.77\angle 180^\circ$ amp. (h) $11.54\angle 120^\circ$ amp. (i) $16.33\angle 75^\circ$ amp. (7) 13.28 amp; 1058 watts. (9) 92.3%; decreases to 77.6%. (11) $\mathbf{E}_{bc} = 100\angle -120^\circ$ volts; $\mathbf{E}_{ca} = 100\angle 120^\circ$ volts; $\mathbf{I}_{AB} = 4\angle -53.1^\circ$ amp; $\mathbf{I}_{BC} = 4\angle -173.1^\circ$ amp; $\mathbf{I}_{CA} = 4\angle 66.9^\circ$ amp; $\mathbf{I}_{aA} = 6.93\angle -83.1^\circ$ amp; $\mathbf{I}_{bB} = 6.93\angle 156.9^\circ$ amp; $\mathbf{I}_{cC} = 6.93\angle 36.9^\circ$ amp; 720 watts (assuming rms values). (13) (a) 13.38 amp. (b) 1497 watts. (c) 0.808 leading. (15) (a) 5.25 amp (or 17.3 amp, which is unlikely). (b) 82.6 watts (or 898 watts). (17) 650 watts. (19) $P_{\text{upper}} = 433$ watts; $P_{\text{middle}} = 217$ watts; $P_{\text{lower}} = 0$ watt. (21) Since the power-factor angle is usually smaller than 30° in magnitude, the two-wattmeter method will provide two positive readings which are reasonably equal. Therefore, only one reading is probably necessary. Insert current coil in upper line, positive terminal to left; insert potential coil between upper two lines, positive terminal on upper line. If a positive reading is obtained, the generating station is to the left. If power-factor angle is doubtful, shift lower terminal of potential coil and take another reading. Then, if sum of two readings is positive, generating station is to the left. Interruption of service may be avoided by connecting current coil before cutting line (or by erecting your own generating station).

(23) (a) $9P^2R_\Delta/E^2$. (b) $3P^2R_Y/E^2$. (c) Delta system has three times the weight and about three times the conductor cost. (d) The weight and cost of the three-phase delta system are about three-quarters of the weight and cost of the single-phase system.

Chapter 20

(2) $a = 0.1$ or 0.3 sec. (4) (a) $i(t) = \frac{8}{\pi^2}\sum_{\substack{n=1\\ \text{odd}}}^{\infty} \frac{1}{n^2} \sin \frac{\pi n}{2} \sin nt$. (b) $i_3 = 0.933$; $i_{10} = 0.979$. (6) (a) 8.11 watts. (b) 0.324 watt. (c) 9.34 watts. (d) 10 watts. (8) $e(t) = 1 + 2 \sum_{n=1}^{\infty} \times \cos 2\pi nt$. (9) (a) Proof. (b) Proof. (11) (a) $f(t) = 3 + \frac{4}{\pi}\sum_{\substack{n=1\\ \text{odd}}}^{\infty} \frac{1}{n} \sin \frac{3n\pi}{2} \cos 5\pi nt$

(b) $f(t) = \frac{4}{\pi}\left(3 \sin 5\pi t - \sin 10\pi t + \sin 15\pi t + \frac{3}{5} \sin 25\pi t - \cdots\right)$

(c) $f(t) = \frac{4}{\pi}\left(\frac{4-\sqrt{2}}{1} \cos \frac{5\pi t}{2} + \frac{-4-\sqrt{2}}{3} \cos \frac{15\pi t}{2} + \frac{4+\sqrt{2}}{5} \cos \frac{25\pi t}{2} + \cdots\right)$

(12) (d) Neither. (e) Even. (f) Neither. (g) Neither. (13) (a) $f(t) = -\frac{2}{\pi}\left(-\frac{3}{1} \sin \frac{\pi t}{10} + \frac{2}{2} \sin \frac{2\pi t}{10} - \frac{3}{3} \sin \frac{3\pi t}{10} - \frac{3}{5} \sin \frac{5\pi t}{10} + \frac{2}{6} \sin \frac{6\pi t}{10} - \frac{3}{7} \sin \frac{7\pi t}{10} \pm \cdots\right)$. (b) $f(t) = \frac{4}{\pi}\sum_{\substack{n=1\\ \text{odd}}}^{\infty}\left[\frac{\cos 2nt}{4n^2-1} + \frac{2n \sin 2nt}{4n^2-1}\right]$. (c) $f(t) = \frac{800}{\pi^2}\left(\frac{0.414}{1^2} \sin \frac{\pi t}{4} + \frac{2}{2^2} \sin \frac{2\pi t}{4} + \frac{2.414}{3^2} \times \sin \frac{3\pi t}{4} + 0 + \cdots\right)$. (15) (a) At any of the zero crossings. (b) At any of the points of "tangency" on the horizontal axis. (16) Answer for $M = 20$ is $a_2 = -0.051$. (18) $e_C = 2(1 - \epsilon^{-t})$, $0 \leq t \leq 0.5$; $e_C = -2 + 2.788\epsilon^{-(t-0.5)}$, $0.5 \leq t \leq 1.5$; $e_C = 2 - 2.973\epsilon^{-(t-1.5)}$, $1.5 \leq t \leq 2.5$; $e_C = -2 + 2.906\epsilon^{-(t-2.5)}$, $2.5 \leq t \leq 3.5$; $e_C = 2 - 2.930\epsilon^{-(t-3.5)}$, $3.5 \leq t \leq 4.5$; see Fig. 52. (20) (a) $e = \cos 10t + 0.25 \cos 9t + 0.25 \cos 11t$. (b) 0.25 watt. (c) 0.281 watt. (22) $f(t) = \sum_{n=-\infty}^{\infty} \epsilon^{j2\pi\omega t}$. (23) Proof. (24) (b) See Fig. 53. (c) $f(t) = 25 + \frac{100}{\pi^2}\sum_{n=1}^{\infty} \frac{1}{n^2}\{[(-1)^n - 1] \cos 2\pi nt - \pi n(-1)^n \times \sin 2\pi nt\}$. (25) (a) $f(t) = \frac{50}{\pi^2}\sum_{-\infty}^{\infty} \frac{(1 - j\pi n) \cos \pi n - 1}{n^2} \epsilon^{j2\pi nt}$. (b) See Fig. 53 again. (c) $f(t) = 25 + \frac{100}{\pi^2}\sum_{n=1}^{\infty} \frac{1}{n^2}\{[(-1)^n - 1] \cos 2\pi nt + \pi n(-1)^n \sin 2\pi nt\}$.

(26) (a) $\mathbf{F}(j\omega) = \dfrac{4\pi \cos \frac{\omega}{4}}{4\pi^2 - \omega^2}$; see Fig. 54*a*. (b) $\mathbf{F}(j\omega) = \dfrac{2\omega \sin \frac{\omega}{2}}{4\pi^2 - \omega^2}$; see Fig. 54*b*. (c) $\mathbf{F}(j\omega) = \dfrac{2\omega \sin \omega}{\omega^2 - 4\pi^2}$; see Fig. 54*c*. (d) $\mathbf{F}(j\omega) = \frac{2}{\omega^2}(1 - \cos \omega)$; see Fig. 54*d*. (e) $\mathbf{F}(j\omega) = 1$; see Fig. 54*e*.

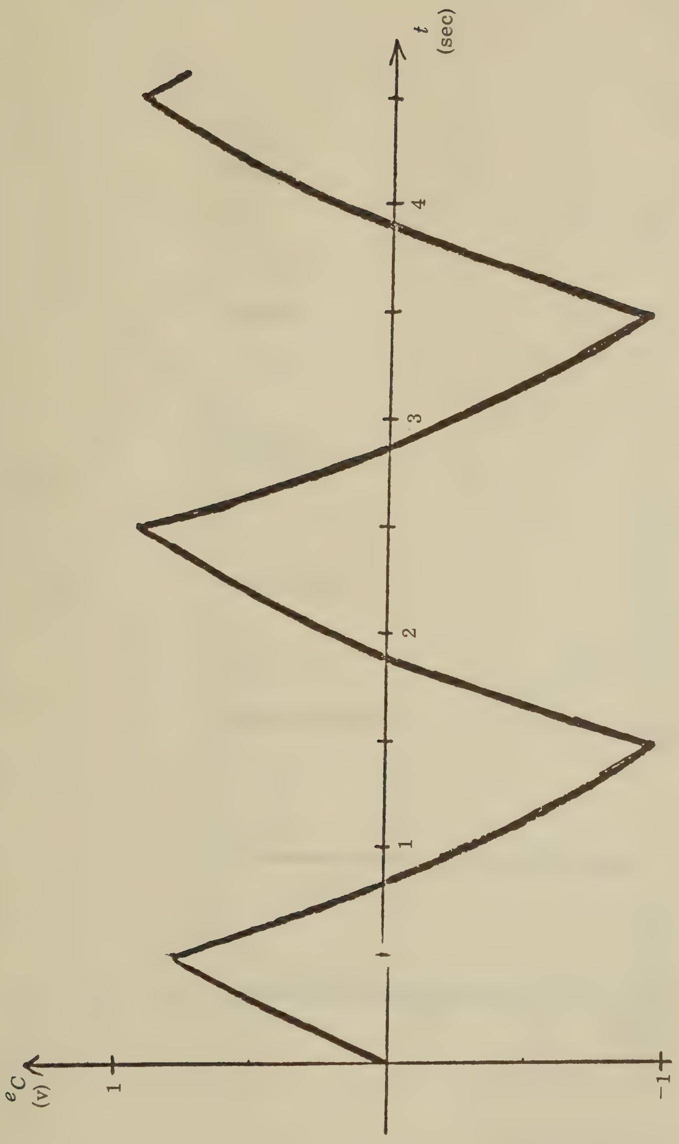


Fig. 52

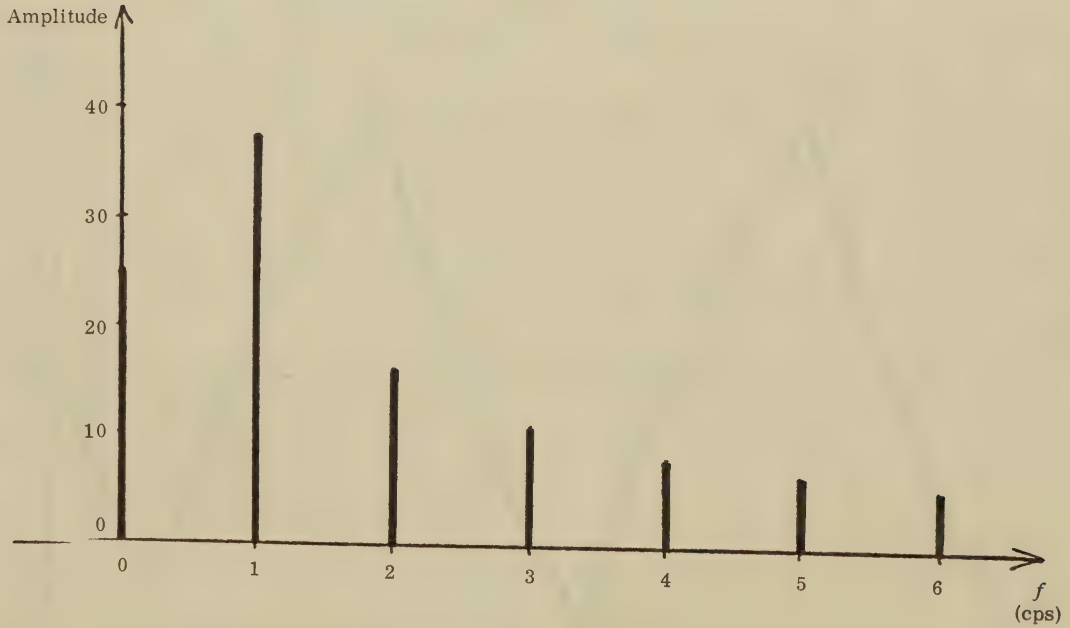
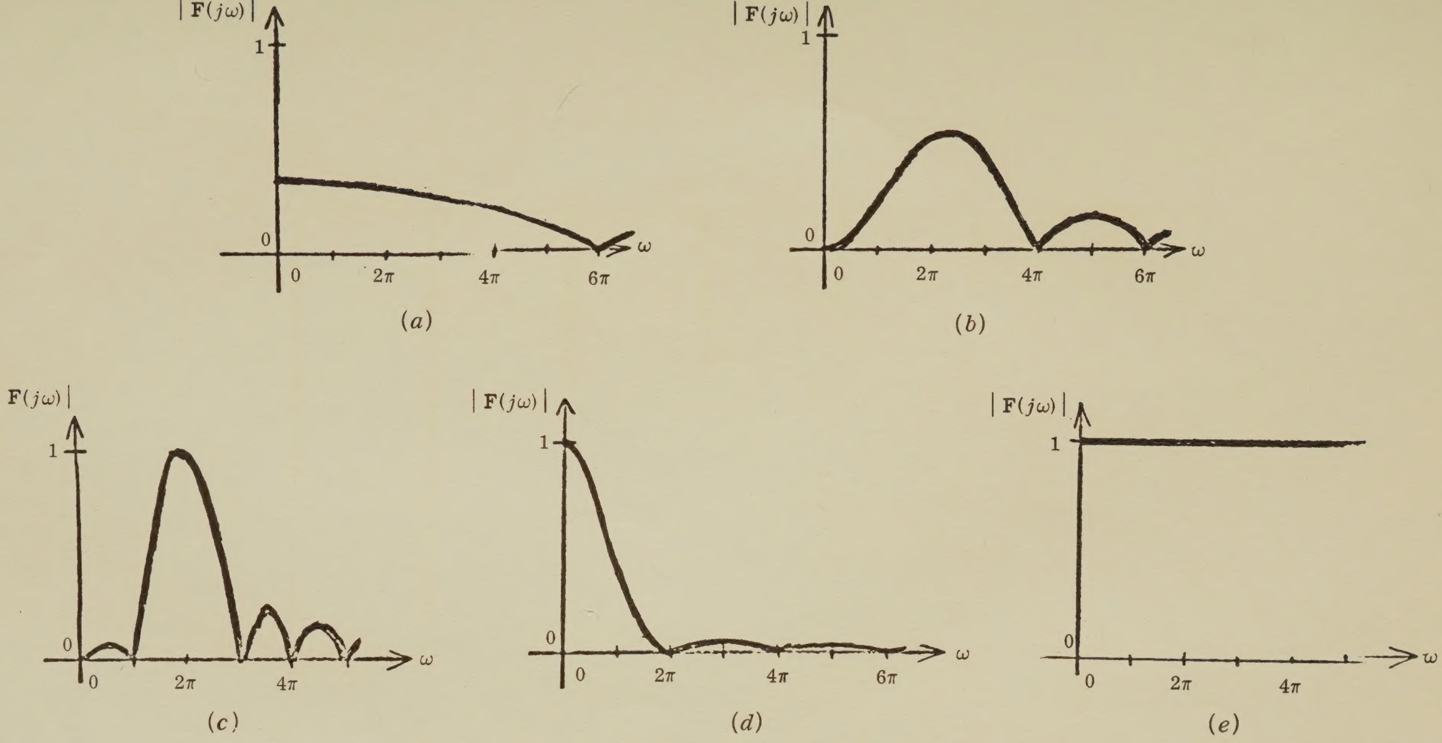


Fig. 53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4π
6π
ω
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|F(jω)|
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0
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ω
(c)
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(d)
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4π
ω
(e)

Fig. 54

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